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Assessment of road improvements in remote and regional areas

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Foreword

Relying on traditional cost–benefit analysis methods, traffic volumes in remote and regional areas are often too low to justify constructing and maintaining roads at standards that approach community expectations. In determining the standards of roads to provide in rural areas, governments and transport planners need to strike a balance between economic efficiency and other objectives. Finding the right balance is subjective. There is no established way to make decisions that bridge this gap between traditional cost–benefit analysis and community expectations. Across remote and regional Australia, conditions vary enormously. At what rate should road standards be allowed to taper off as areas become more remote? There is a risk of decision-making about remote and regional roads being inconsistent and opaque.

This landmark report proposes a way to integrate recent thinking about equity and distributive justice from literature in the disciplines of philosophy, economics and transport planning with cost–benefit analysis methods. It also examines social and wider economic benefits that could legitimately be considered in cost–benefit analysis of remote and regional road projects. It is intended to offer greater transparency, consistency and fairness in decision-making between projects in different locations and times.

A great deal of investigation and conceptual thinking has gone into this very detailed report and methodologies, and this novel framework may take time to gain acceptance across the transport planning profession.

I commend it to you, the reader, and congratulate the author on this valuable contribution to the intellectual and practical progress of transport economics.

Georgia O'Cianain

Head of Bureau

Bureau of Infrastructure and Transport Research Economics

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At a glance

Low population densities in remote and regional areas lead to low traffic volumes, which makes it difficult for traditional cost–benefit analysis (CBA) methods to support road improvements in these areas in line with community expectations and government policy objectives. Roads in remote and regional areas are often provided at standards above what would be considered economically efficient levels under traditional CBA methods, but there is currently no clear way to make a recommendation as to an acceptable standard. Methods such as multi-criteria analysis and subjective judgement give rise to risks of inconsistent and unfair decisions across projects, locations and time.

This report develops ways to improve the efficiency, equity and transparency of decision-making for road funding in remote and regional areas. CBA is retained as the core appraisal tool, with the additions of (1) social benefits, (2) wider economic benefits (WEBs), and (3) equity weights. Each of the 3 sets of methodologies stands alone and can be implemented without the others.

Social benefits and WEBs are not part of the traditional approach to CBA of non-urban roads. However, being economic efficiency impacts, they can legitimately be added to CBAs.

Social benefits arise because people under-perceive the full value to themselves and to their communities of trips for education, healthcare and employment reasons. For each trip purpose, the report provides social benefit values in dollars per trip for CBA practitioners to use to estimate social benefits. Social benefits apply only for additional trips induced by a road improvement. The report supplies a methodology to forecast additional trips based on connectivity indexes. The connectivity indexes measure accessibility to service centres within a 200km radius, taking into account travel times and the sizes of the service centres.

WEBs relevant to remote and regional roads arise from imperfect competition in product and labour markets, and taxes on labour. Two types of WEBs are likely to occur for projects and are straightforward to estimate, but the others will be less common and have greater informational requirements to justify and estimate.

Inclusion of social benefits and WEBs in CBAs of remote and regional road improvement projects will usually only have a small impact on CBA results, insufficient to support investment decisions that align with community expectations and government policy objectives. Equity has to be considered.

Equity in transport relates to accessibility. Accessibility is a separate sphere of justice from income distribution. The report examines relevant theories of equity. The recommended approach involves multiplying benefits in CBAs by equity weights. The weights are one above a threshold connectivity index level and hence have no effect. Below the threshold, the weights increase with remoteness as measured by the connectivity indexes. Suggestions are given for calibrating the equity weighting function. Calibration would be done by road agencies at the program level.

Economists have been reluctant to use weights in CBAs. The report provides a strong justification for equity weights based on academic literature and advantages over the alternatives. The report recommends that weighted CBA results never be reported without also reporting unweighted results.

The report also recommends that CBA practitioners applying the methods present an accompanying ‘narrative’. The narrative explains and justifies the applications of the methods and ensures consideration of any local circumstances that could determine whether the benefits claimed are likely to be realised and whether equity weighting is appropriate.

The report offers a rigorous, transparent approach to assessing investments to upgrade roads in remote and regional areas that takes account of social, economic and equity impacts and should promote greater consistency and fairness in decision-making.

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List of abbreviations

AADT	average annual daily traffic
ABS	Australian Bureau of Statistics
ACARA	Australian Curriculum, Assessment and Reporting Authority
ACCC	Australian Competition and Consumer Commission
AIHW	Australian Institute of Health and Welfare
ARIA	Accessibility and remoteness index of Australia
ATAP	Australian Transport Assessment and Planning
BCR	benefit–cost ratio
CBA	cost–benefit analysis
BITRE	Bureau of Infrastructure and Transport Research Economics
CI	connectivity index
DE	Department of Education (Australian Government)
ECE	early childhood education
GCSE	general certificate of secondary education
MBCR	marginal benefit–cost ratio
MC	marginal cost
MDA	median age of death
MLC	marginal labour cost
MRP	marginal revenue product
NEMT	non-emergency medical transportation
RA	remoteness area
SA	statistical area
SWF	social welfare function
UCL	urban centres and localities
UK Dft	UK Department for Transport
VTTS	value of travel time savings
WEB	wider economic benefit
WTP	willingness to pay

Executive summary

Introduction (Chapter 1)

Access to other people, activities, markets and services via transport and communications networks is essential for the wellbeing of individuals and society as a whole, and is perhaps even a fundamental right. Access via transport and communications networks is more expensive to provide in places with less dense populations as distances between people are greater and there are fewer people to share the costs. In network industries such as telecommunications, postal services, railways, electricity and water supply, services in rural areas are usually provided at below cost. The analogue for roads is spending to provide standards above economically efficient levels as indicated by cost–benefit analysis (CBA). CBAs of road improvements in remote and regional areas often forecast benefits below costs because of low traffic volumes.

Provision of roads at standards above economically efficient levels in remote and regional areas is expected by the community and required by governments to support their regional policy objectives. The problem addressed by this report is how to decide which project proposals to accept and reject when achieving a benefit–cost ratio (BCR) greater than one is no longer the primary investment criterion. Instead, competing objectives of economic efficiency and equity need to be balanced. Provision of uniform standards for all roads would not be affordable unless the uniform standard was set extremely low. Equitable standards are a compromise between economically efficiency and uniform standards. The amount of economic efficiency that the community is willing to sacrifice is greater where the road project benefits people who are more disadvantaged in terms of accessibility.

The approach in this report is, first, to investigate whether there are additional benefits that can be added to CBAs of remote and regional road upgrading projects, that are not included in the conventional CBA methodology. To be legitimate additions to CBAs, the benefits have to improve economic efficiency. Second, the report investigates equity justifications for accepting road improvements with BCRs below one and use of equity weights in CBAs.

The framework is intended to be transparent, to recommend an appropriate trade-off between the economic efficiency and equity objectives, and to promote consistency in decisions across different projects, locations and times. Decision-making via alternative methods such as multi-criteria analysis and subjective judgement is unlikely to have these attributes.

Economic foundations (Chapter 2)

CBA, being based on welfare economics, is normative, meaning that it points to 'what s*hould be*', in contrast to positive economics, which concerns 'what *is*'. CBA adds up gains and losses to all members of society from a proposed project and supports a recommendation according to whether the result is positive or negative. Gains and losses to different individuals can be added together, because they are expressed in a common unit of money. Economic theory shows that this is, to an extent, biased against low-income people because a dollar is worth more to them than to high-income people. Economists have proposed utility weights with which to adjust benefits and costs in CBAs to counter the effect.

For most road improvements, benefits accruing to road users are predominantly savings in travel times, followed by savings in vehicle operating costs, then reduced crash risk. Time savings are monetised using a value of travel time savings. Willingness-to-pay (WTP) values to save time and crash risk tend to be higher for people with higher incomes. However, CBAs of transport projects use 'equity values' for time and safety, set to correspond with the average or median income level. This makes utility weighting unnecessary. Later chapters of the report recommend equity weights, which are related to accessibility and reflect the moral or ethical judgements of decision-makers, unlike utility weights, which reflect the marginal utility of income.

Each additional dollar invested in a road segment to make it smoother, wider, straighter, flatter, or safer generates a benefit to users, but there are diminishing returns. Eventually, the point is reached where further improvements are of no value because road users are able to travel at the standard maximum speed limit outside built-up areas in safety with minimal interaction with other vehicles. Setting aside lumpiness in road investment (for example, that the number of lanes must be an integer), the economically optimal level of investment in a road segment occurs where the benefit from investing an additional dollar (the marginal benefit–cost ratio, MBCR) falls to one. For example, it would be economically efficient to invest an additional dollar for a benefit of $1.10, but not for $0.90.

Accessibility (Chapter 3)

In the transport planning context, accessibility refers to the ease with which individuals can reach desired activities or services depending on the associated transport costs. Poor accessibility can restrict people's ability to participate in normal relationships and activities, potentially resulting in social exclusion.

The methods introduced in this report use accessibility measures to (1) forecast trips induced by transport improvements for the purpose of estimating social benefits, and (2) calculate weights with which to inject equity considerations into CBAs. The recommended accessibility measure, called the 'connectivity index' (CI) is derived from the random utility model. The CI for a given origin is a function of the travel times to destination zones (impedance) and the population sizes of those zones (attraction).

CIs were calculated for almost 18,500 ABS Statistical Area 1s (SA1s) outside the Major Cities category in the ABS Remoteness Area (RA) geographic structure, using Urban Centres and Localities (UCLs) as destinations. The CI is focussed on regular commuting trips, achieved by only counting destination UCLs with centroids within a 200km radius of each SA1 centroid. Long-distance trips are thereby excluded.

The CI has 2 parameters — one controlling how fast the CI declines with travel distances, the other controlling how fast the CI rises with the population sizes of destinations. Parameter values were estimated for 3 trip purposes — education, healthcare and employment. Regression analyses were undertaken of estimated numbers of trips per person per day against CIs together with other independent variables to obtain the best-fitting parameter values.

Average CI values were calculated for SA1s in each of the 4 ABS RA categories outside the Major Cities RA (Inner Regional, Outer Regional, Remote, and Very Remote). The more remote the RA, the lower the average CI, which is as expected. There are, however, overlaps, as illustrated by the fact that the maximum CI within each RA category is well above the average for the category above. This can be explained by the fact that the RAs were defined using the ARIA+ index, which is based on much greater ranges of distances between origins and destinations. Also, the RA boundaries were set to avoid leaving isolated SA1s surrounded by other SA1s in a different category.

Relationships were examined between the CIs and key statistics from the 2021 Census at the SA1 level. The SA1s with the lowest CIs have relatively low median ages and personal income levels, and moderately high percentages unemployed reflecting the high percentages of First Nations people in the most remote areas. For the data considered as a whole, the relationships with census variables are weak.

The regression analysis provided coefficients for the number of additional trips per person per day that would result from a one unit increase in the CI for 5 trip purposes — early childhood education (ECE), primary and secondary education, tertiary education, healthcare and employment. The coefficients can be used to estimate induced trips from an SA1 following a road improvement that increases the CI for that SA1. The increase in trips per person needs to be multiplied by size of the relevant population in the SA1, to obtain the number of induced trips per day.

Social benefits (Chapter 4)

All benefits in CBAs are 'social benefits' in the usual sense of the term, because they accrue to members of society. But in the absence of an accepted term, 'social benefits' is used in the report to refer to quality-of-life benefits, specifically in relation to education, healthcare and employment. The social benefits referred to here are genuine economic efficiency benefits. They arise from the market imperfections of

- individuals not recognising the full value to themselves and their families of increased use of road transport to access healthcare, education and other services
- quality-of-life benefits to other community members (positive externalities) from better health, education and employment outcomes for individuals in the community
- savings in costs to governments in provision of services in areas such as health, education, law and order, and remedial social programs.

Social benefits, as defined here, exist only for trips induced by a project. The social benefits associated with existing trips will accrue in both the base case and project case, and so are not additional benefits attributable to the project being assessed.

For each of 5 trip purpose categories, a dollar net benefit amount per additional round trip was estimated. These are intended for use by CBA practitioners, multiplying by the number of induced trips per year to estimate social benefits.

- For **ECE**, a benefit value of $71 per round trip at a 3% discount rate was derived from a CBA of one year of ECE, dividing net benefits by the number of children and trips year. Benefits in the CBA included higher parental earnings, higher earnings by children over their lives, and higher taxes accruing to governments. Costs comprised spending by governments and households. The benefit values fall to $48, $35 and $5 per trip at the 4%, 5% and 7% discount rates respectively.
- Benefits per additional round trip for **primary, secondary and tertiary education** were estimated by combining results of a recent econometric study of the impacts of additional years of education on annual earnings with earnings data from the 2021 Census. Costs of providing the education were deducted and forgone earnings during years of education excluded. Benefits per trip for primary and secondary education are $628, $468, $349 and $190 at the 3%, 4%, 5% and 7% discount rates respectively. For tertiary education, the respective benefit values are $736, $517, $356 and $149.

Gross benefits for all categories of education were increased by 30% to allow for positive non-pecuniary externalities of improved outcomes to governments and broader society in relation to health, crime, and social cohesion. The 30% is based published sources.

- For **healthcare**, a benefit value from an additional round trip to a GP of $3000 was obtained by regressing data at the SA3 level on median age of death against GP visits per person per annum and other explanatory variables. The additional year of life from an additional GP visit, other things held equal, was multiplied by the value of a life year. The average cost per visit was deducted.
- The **employment** benefits from an additional round trip are estimated to be $115. The employment benefit has 2 components
  - $55 being the additional income tax and payroll tax accruing to governments (actually a wider economic benefit, the subject of Chapter 5), and
  - 30% of before-tax earnings for positive non-pecuniary externalities, the same allowance as for the education benefit estimates.

Wider economic benefits (Chapter 5)

Like the social benefits of Chapter 4, wider economic benefits (WEBs) arise from market imperfections and would not be counted in conventional transport CBAs. In the case of WEBs, the imperfections occur in product and labour markets. Transport CBA guidelines provide methods for estimating 3 types of WEBs expected to result from large transport projects in cities. The report considers whether each of these 3 WEBs, plus a further 3 potential WEBs, might apply for transport schemes in remote rural areas.

- **Agglomeration economies** are not relevant for road projects in remote and regional areas.
- **Taxes on labour** were addressed in Chapter 4 and included in the employment social benefit estimate.
- **Output changes in imperfectly competitive markets** occur where a transport improvement reduces costs for local firms that charge prices above costs, and in response, the local firms lower their prices and

expand output. These can be relevant in rural areas and are straightforward to estimate, being 10% of project benefits accruing to business cars and freight vehicles.

- Changes in competition can occur where a firm with a **local monopoly** is forced to reduce its prices as a result of cheaper access for local consumers to goods and services elsewhere because of a road improvement. The benefit is the difference between the price and the cost of additional consumption as a result of the price fall.
- In labour markets where employers have **monopsony power**, they can hold wages down below levels that would otherwise occur. Reductions in travel time and costs could give local workers an opportunity to earn more by working for another employer within commuting distance, after deducting the generalised costs of the additional commuting. To compete, the local employer would be forced to raise wages and employ more local workers. The recommended benefit value is 20% of the wage rate of the additional local workers employed.
- **Involuntary unemployment** can occur where the wage rate is assumed to be fixed by governments or unions at a level above the rate that is determined by a competitive labour market. Formulas are provided for
  - a shadow wage rate applicable in CBAs to otherwise involuntarily unemployed workers who obtain employment in constructing the road project being assessed (not a WEB in the accepted sense of the term)
  - the WEB arising where the transport improvement leads to increased employment in product markets.

Estimation of WEBs for taxation of labour and output changes in imperfectly competitive markets is straightforward and broadly applicable to road improvements in remote and regional areas. The latter 3 WEB types will be less common and informationally quite demanding to justify and estimate. An economic impact study would be needed to support estimation of the monopsony labour market and involuntary employment WEBs. Estimated increases in employment used to calculate these WEBs should be net of labour displaced elsewhere. The monopsony labour market and involuntary employment WEBs cannot coexist for the same occupation in the same location.

Equity (Chapter 6)

Incorporating social benefits and WEBs into CBAs of remote and regional road projects will have only a small impact on CBA results, in most cases insufficient to support investment decisions that align with community expectations and government policy objectives. Equity arguments need to be considered. Relevant theories of equity and justice from academic literature were reviewed to find an approach suitable to apply to remote and regional roads and that fits with the CBA framework.

Human wellbeing has multiple dimensions such as human rights and liberties, income and wealth, and access to education, healthcare, and housing. An equitable distribution among members of society in one these ‘spheres of justice’ does not imply there is an equitable distribution in the others. Authors in the transport planning discipline, in particular Martens, have argued that accessibility should be treated as a separate sphere of justice. The question then arises: what is a fair level of accessibility taking into account the costs of improving accessibility?

Relevant equity concepts were examined.

- **Utilitarianism** aims to maximise the sum of individual utilities. Like CBA, it pays no attention to whether benefits and costs accrue to the rich or the poor, and so does not address equity.
- **Rawls’ ‘difference principle’** only allows inequalities where they improve the wellbeing of the worst-off members of society. This creates an incentive for talented and motivated people to generate income to benefit themselves and, in doing so, benefit others. A drawback is that the difference principle would endorse large transfers of resources from society in general to provide very small amounts of benefit to the least well-off. In the academic literature on equity, transfers in which the transferor loses more than the transferee gains are said to be ‘leaky’. Deadweight losses arising from the effect of taxes on

incentives, administration costs, and investing in roads beyond the point where the MBCR equals one are sources of leakage in transfers.

- **Sufficientarianism** aims to ensure everyone has 'enough'. Priority is given to improving the wellbeing of people below a threshold deemed to be 'sufficient'. Martens has proposed that sufficientarianism be adopted as the guiding principle for promoting equitable accessibility in urban transport policy and planning. However, to provide a minimum standard of accessibility above a low level outside city boundaries would be prohibitively costly in areas of low population densities — a very leaky transfer.
- **Prioritarianism** holds that an improvement in an individual's wellbeing is morally more valuable, the worse-off the person would otherwise be. In other words, it gives priority to people with lower wellbeing levels. Applied to CBAs, prioritarianism leads to weighting of benefits, with the highest weights assigned to benefits accruing to the worst-off, and weights progressively falling as wellbeing increases. The weights are set via a mathematical function. Prioritarianism allows leaky transfers to occur but only to a controlled extent. Equity weights reflect the moral or ethical judgements of decision-makers and are therefore distinct from utility weights, which reflect diminishing marginal utility of income for consumers.

The approach recommended in this report for CBAs of road improvements in remote and regional areas is a combination of prioritarianism and sufficientarianism. Above a threshold level of accessibility, measured by the CI, weights are set to one and therefore have no effect. As accessibility declines below the threshold, weights progressively increase up to a set maximum level.

Equity weighting model (Chapter 7)

A mathematical model is developed to understand the implications of the recommended accessibility weighting system. The model derives the optimum spending level on roads leading from each zone maximising the sum of utilities of all individuals in society. Utility for each individual is the sum of utility from income and utility from accessibility in the zone in which they reside. All individuals are assumed to have the same income level. This restricts the focus of the model to addressing equity solely in the accessibility sphere of justice, and is consistent with the extremely small correlation between the CIs and median personal income for SA1s. In the model, spending on roads is funded from a tax deducted from the income of each person regardless of zone of residence.

The optimum solution balances the marginal utility of income from an additional tax dollar transferred to road spending against the marginal utility of accessibility from spending an additional dollar on roads in each zone. Without any equity weighting, maximising the sum of utilities (the utilitarian approach) leads to the most economically efficient outcome. This is not surprising because everyone has the same marginal utility of income. The result changes when utility from accessibility in each zone is multiplied by an equity weighting function dependent on the level of accessibility. For zones with CIs above the threshold CI, the weight is one and there is little change in road spending for those zones. For zones with CIs below the threshold, spending is increased past economically efficient levels, funded by a higher tax than otherwise.

A more complicated version of the model, in which each origin zone has multiple destinations and each road segment forms part of the route for trips with different origins and destinations, shows that the weight for each SA1 should be applied to benefits to traffic originating in that SA1.

Two types of equity weighting function are discussed.

- The **isoelastic function** results in small weights above one to SA1s with CIs over a large range below the threshold and increases the weights rapidly as CIs reduce towards the levels of the most remote zones. Specification of a maximum weight is essential because the weights approach infinity as CI approaches one from above.
- The **linear function** causes weights to rise more rapidly below as accessibility falls below the threshold and gives zones with intermediate CIs below the threshold higher weights compared with the isoelastic function.

The isoelastic function will concentrate road upgrading in the least accessible areas and might be preferable if an objective was to reduce social exclusion in the most remote areas. The linear function will spread the upgrading works towards areas with intermediate levels of accessibility. The isoelastic function would favour improving accessibility for remote First Nations communities while the linear function would shift the balance somewhat towards rural areas where agriculture and mining are the main economic activities. Other functional forms could be considered.

The equity weights could be calculated from any of the 3 trip-purpose CIs (education, healthcare and employment). Which one is selected makes little difference to the weights. The employment CI was used in the examples in the report because the weights calculated from the employment CI lay in between the weights calculated from the education and healthcare CIs.

Implementation (Chapter 8)

Calibration of the equity weighting function would be done by road agencies at the program level, not by CBA practitioners.

Calibration requires decision-makers to set 3 parameters

- the threshold CI below which weights start to increase above one as CI reduces with remoteness
- the maximum allowable value for the weights
- the CI below which the maximum weight applies.

The maximum allowable weight limits extremely wasteful spending on roads. For example, a maximum weight of 3.0 would let through projects with BCRs down to one-third. Where low traffic volumes lead to very low BCRs and small total benefits, decision-makers should consider whether there are more cost-effective ways to promote the wellbeing of the intended beneficiaries.

The following considerations enter into setting the parameter values for the equity weighting function:

- the ethical judgements of decision-makers as to what is fair and reasonable, including long-term objectives to raise or lower standards of road provision in remote and regional areas
- budgetary impacts. The higher equity weights are set, the greater will be the demand for road spending.
- precedents set by existing standards of road provision. They indicate what communities are accustomed to and set a baseline for decisions about whether to raise or lower standards of road provision in areas of similar accessibility. People compare the standards of roads in their own regions with those in other regions with similar economic, social and environmental characteristics.

The effects of varying the equity weighting function parameters could be tested on past CBAs or CBAs of hypothetical road upgrading projects with realistic costs and benefits.

CI values at various percentiles of populations for ABS RAs and used as reference points. An example would be to set the CI parameters such that 75% of the population in the Outer Regional RA would have an equity weight above one and 25% of the population of the Very Remote area have the maximum weight.

The methods developed in this report are aimed at remote and regional roads, not roads in metropolitan areas. They are unlikely to be warranted for inner regional areas. Boundaries might be set based on a given minimum weight above one.

It might be considered that people who voluntarily choose to live in areas with poor access do not warrant special consideration. Some people may prefer living in a rural area because of the lifestyle. Based on contextual knowledge, an analyst undertaking CBA might recommend not applying an equity weight to traffic from a SA1 where residents are content to be isolated.

The CI formula makes no allowance for inconvenience and costs suffered by residents during periods of road closure due to natural disasters. Where a road project raises flood resilience, social benefits could be estimated for trips no longer missed as result of road closures. Equity weights would be applied.

The methods in this report apply to car traffic only with the exception of the WEBs related to imperfect competition.

Equity weighting is a form of 'adjusted CBA' as described in the ATAP CBA guideline (T2). This report echoes the recommendation in the ATAP guideline that CBA results adjusted with equity weights never be reported separately from the results of the CBA without weights. Decision-makers should be aware of the amount of economic efficiency gains forgone in order to promote equity objectives

This report recommends that CBAs applying any or all of the methods in this report, explain and justify the applications with a narrative. The idea of requiring a narrative comes from government guidelines for estimating WEBs. An example is where social benefits are claimed for additional trips to access education, healthcare, or employment. Analysts should confirm and report on whether the necessary education or healthcare facilities, or job opportunities exist in the locations to which the road project improves access. The report also suggests other questions to address in narratives.

Conclusion (Chapter 9)

Each of the 3 sets of methods in report — social benefits, WEBs and equity weighting — stands alone and can be implemented by itself without the others.

This report offers a rigorous, transparent approach to assessing investments to upgrade roads in remote and regional areas that takes account of social, economic and equity impacts and should promote greater consistency and fairness in decision-making across projects, locations and over time.

1. Introduction

1.1 Community service obligations in road supply

Access to other people, activities, markets and services via transport and communications networks is essential for the wellbeing of individuals and society as a whole, and is perhaps even a fundamental right. However, access via transport and communications networks is more expensive to provide in places with less dense populations as distances between people are greater and there are fewer people to share the costs. Where services are provided by private firms or government business enterprises, prices set to recover costs will be much higher in remote and regional areas than in cities, which many would judge to be inequitable. In such cases, governments have legislated for 'community service obligations' whereby private or government-owned enterprises have been required charge prices below costs for services in regional areas.[1] Often, loss-making services are cross-subsidised from profits made in urban areas. The necessary profits in urban areas are made possible by the 'natural monopoly' status of these firms. Today, telecommunications supplier Telstra is subject to a 'universal service obligation performance agreement' and Australia Post has legislated community service obligations.

During the late 1980s and 1990s, as part of the drive for micro-economic reform, efforts were made to identify and cost community service obligations in a number of industries — telecommunications, postal services, railways, electricity, water (BTCE 1989; Industry Commission 1997). Roads escaped this kind of scrutiny because they are regarded as a public good provided by governments out of general revenue. Revenue collected from road users in the form of fuel excise and registration fees is not connected to road provision. In the absence of commercial criteria, economically optimal road standards are determined by cost–benefit analysis (CBA) (ATAP 2019a O5). Road improvements are economically warranted as long as the present value of benefits minus costs is positive, or the benefit–cost ratio (BCR) exceeds one. With benefits from road projects being assessed with CBAs almost proportional to traffic volumes, projects in remote and regional areas are often unable to pass the CBA test.

A community service obligation for road provision could be considered to arise where the government supplies a road at standard above the economically efficient level determined by a CBA. For example, if raising the standard of a road from gravel to sealed or from 2 lanes to 4 lanes had a BCR of 0.8, then the benefits to the community would amount to 80% of the costs. The 20% loss to society as a whole could be considered the cost of the community service obligation.

There have been no published assessments of economically efficient spending compared with actual spending on roads in Australia since the 1970s. BTE (1979, p. 151) reported that for Australia as a whole, almost half of total spending on rural local roads over the period 1974-75 to 1978-79 was economically inefficient. For rural arterial roads, actual spending exceeded economically efficient spending in 2 states, NSW and Victoria. Discussing this finding, Stanley & Starkie (1983, p. 195) suggested that much of the explanation lies in rural local roads being a 'merit good'.[2]

> By implication, the wider community derives benefits from a level of provision of rural local road services in excess of a willingness to pay by road users to pay for these facilities. Thus fundamental access which local roads provide in rural areas, is viewed like education, health, law and order, as a basic right. (Stanley & Starkie 1983, p. 195)

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1 A definition is: "A Community Service Obligation arises when a government specifically requires a public enterprise to carry out activities relating to outputs or inputs which it would not elect to do on a commercial basis, and which the government does not require other businesses in the public or private sectors to generally undertake, or which it would only do commercially at higher prices" (Industry Commission 1997, p. 7).

2 Although Stanley & Starkie (1983) referred only to local roads, the same issues are relevant to state roads. See, for example, Pelevin et al. (2001).

The 'merit good' concept had its origin in Musgrave (1959, pp. 13-14). Merit goods are subsidised by governments to support provision in amounts above the levels that would be provided by markets. In addition to the direct benefits accruing to the consumers of the goods, merit goods are motived by positive externalities to the broader community and notions of equity. By their very nature, merit goods involve over-riding consumers' preferences as expressed by willingness to pay.

1.2 Problem addressed by the report

Provision of roads at standards above economically warranted levels is expected by the community and required by governments to support their regional policy objectives. The problem addressed by the report is how to decide which project proposals to accept and reject when achieving a BCR greater than one is no longer the primary investment criterion. The framework is intended to be transparent, provide an appropriate trade-off between the economic efficiency and equity objectives, and improve the consistency of decision-making across different projects, locations and time.

Often there is no conflict between the efficiency and equity objectives. But where equity in society can only be improved by sacrificing economic efficiency, it is important to recognise the opportunity costs and achieve a balance. Economic efficiency has to be a major consideration in government decision-making on infrastructure investments because resources have opportunity costs — consuming resources in one use means they are not available for other uses. Equity in road provision also has been a major consideration in government decisions because people with poor road access have less ability to participate in a range of activities crucial for wellbeing and a full participation in society — activities such as employment, education, healthcare, recreation, and socialising. The question of equity versus efficiency is possibly becoming more difficult to address for rural roads due to declining populations in many remote and regional communities[3] and road access being restricted by more severe and frequent flood events.

Figure 1.1 illustrates the problem with hypothetical relationships between efficient and equitable road standards as a function of road usage. With project benefits for the most part proportional to traffic levels, more costly road upgrades, when subjected to the CBA test, can only be justified on more highly utilised roads. Economically efficient standards will, other things being equal, rise with traffic volume, and hence with population density.[4] Furthermore, the costs of upgrading the long lengths of roads that connect rural Australia are high. Construction costs per kilometre are usually higher in remote and regional areas due to the need to bring materials (sometimes including water) and equipment from further away.

However, the community considers that economically efficient standards for low-trafficked roads are unacceptably low. Efficient standards therefore have to be moderated as shown by the more gently sloping equitable standards line. The community and governments accept lower standards being provided for less-trafficked roads, but not to the full extent that CBA of road improvements would dictate.[5] It is a matter of balancing competing objectives of economic efficiency and equity. The gap between economically efficient and equitable standards widens towards the left side of Figure 1.1 because the community is willing to incur progressively greater costs to improve the position of more disadvantaged people.

The right side of Figure 1.1 shows equitable standards for high-trafficked roads falling below economically efficient standards. This could occur where funding constraints on road agencies lead to shifting of funds from high to low traffic roads to meet equity objectives. Whether there is under-investment in high-trafficked roads is outside the scope of this report.

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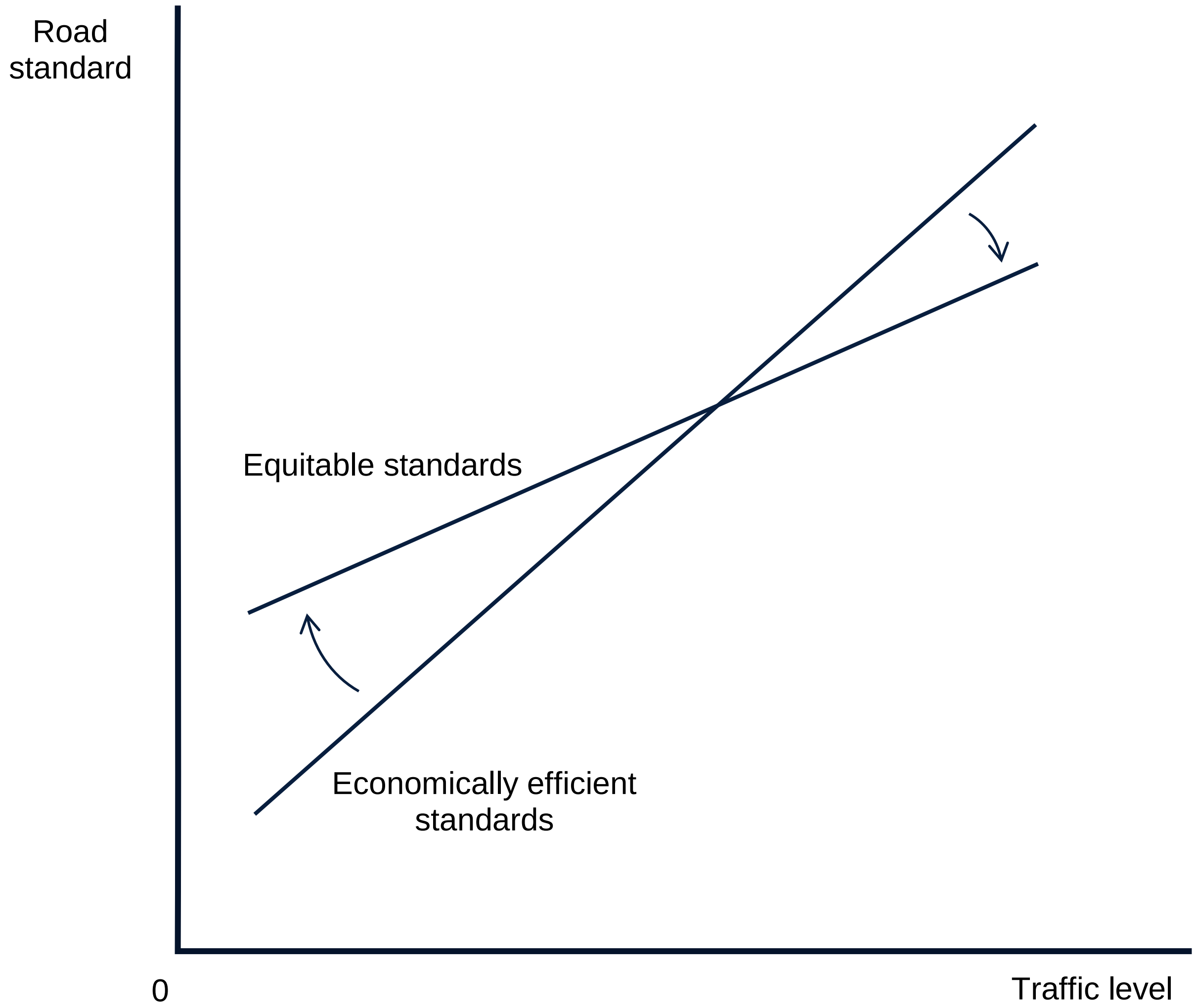
3 The trend annual population growth rates over the 10 years from 2014 to 2024 for the Very Remote category in ABS's RA geography is negative for Australia as whole (–0.30%) and for 4 states — NSW (–1.80%), Queensland (–0.12%), South Australia (–0.54%) and Western Australia (–0.82%). For the Remote category, growth rates were negative in NSW (–1.12%), Victoria (–0.52%) and Queensland (–0.16%). ABS Data download: Population estimates by LGA, Significant Urban Area, RA and electoral division, 2001 to 2024 https://www.abs.gov.au/statistics/people/population/regional-population/2023-24/32180DS0004_2001-24.xlsx

4 Vehicle mix, that is, proportions of business cars, light commercial vehicles, and trucks of various sizes, also affects benefits.

5 Based on interviews with rural road users, Emmerson & Miller (1983, p. 79) reported that, 'Users acknowledged that the satisfaction of their wishes for road works would require more expenditure. They were aware that government funds are not limitless, and were reluctant to make increased contributions to those funds.'

Figure 1.1 Illustrative relationship between economically efficient and equitable road standards



Setting 'minimum standards' is sometimes seen as a way to establish basic equity in areas such as human rights, education and healthcare. The idea of minimum standards is supported by the theory of distributional justice known as 'sufficientarianism', which is discussed in Chapter 6. However, application of a uniform minimum standard above a basic level over a large part of the road system with widely varying traffic volumes would be prohibitively costly. Say a decision was made to implement a minimum standard of all public roads being sealed. In 2023, Australia had 463,000km of paved roads and 859,000km of unsealed roads (BITRE 2025, pp. 121-4). The cost of sealing all currently unsealed roads would be huge, and since, for the most part, these unsealed roads have the lowest traffic levels in the network, the benefits would be small in comparison. A series of minimum standards would have to be set for different classes of roads rising in steps patterning the equity line in Figure 1.1. The problem of setting the levels for the stepped minimum standards remains.

Assessment of equity involves making value judgements and is therefore subjective. The question then is how best to determine, for individual project proposals, how much economic efficiency to sacrifice to promote equity.

Making a subjective decision for each individual project proposal, in other words, decision-makers weighing up CBA results against social impacts case-by-case, is likely to lead to inconsistent decision-making. Different decision-makers at different times, relying on project impact statements from different authors, are unlikely to make the same decision in the same circumstances. There is a risk of inequities in the sense of people in similar circumstances being treated differently, or people with one level of disadvantage receiving more favourable treatment than people with a higher level of disadvantage. Consistency in decision-making ensures fairness in that people with the same degree of disadvantage and costs of reducing that disadvantage are treated equally. People compare the standards of roads in their own regions with those in other regions with similar economic, social and environmental characteristics (Stanley & Starkie 1983, pp. 196-7; Emmerson & Miller 1983, p. 58).

Multi-criteria analysis (MCA) involving quantitative scores and weights is sometimes proposed as a way to make decisions where efficiency and equity have to be balanced (for example, Thomopoulos & Grant-Muller 2013). A number of objectives are set and each given a weight. Each project impact is assigned a score on a scale such as –5 to +5 or 1 to 10 according to how it is judged to perform against each objective. Projects and options are ranked according to the weighted sum of scores. ATAP (2021 F3, p. 15) recommends MCA for sifting long lists of project options but not for selection of the preferred option. MCA cannot indicate whether a project, considered in isolation from all other projects, should or should not proceed. It can only be used to compare projects that are similar. MCA has been extensively criticised. Criticisms include the high level of subjectivity in determining scores and weights, adding together incommensurable impacts, lack of discounting to account for benefits and costs with different timings, and high likelihood of double-counting (Dobes & Bennett 2009; Dobes et al. 2016, pp. 153-8; Ergas 2009; BTE 1999, pp. 187-204; Lucas et al. 2016, p. 476).

CBA is a standard technique that assesses project proposals in a defensible, comprehensive, transparent and rigorous way (ATAP 2022a T2, p. 3). The approach in this report retains CBA as the core assessment tool in line with the ATAP Guidelines (ATAP 2021 F3, p. 15). The report first investigates whether there are additional benefits that can be included in CBAs of remote and regional road upgrading projects that are not included in the conventional CBA methodology. To be legitimate additions to CBAs, the benefits have to improve economic efficiency. Second, the report investigates equity justifications for accepting road improvements with BCRs below one and the use of 'equity weights' in CBAs.

1.3 The value of roads in remote and regional areas

Good quality, efficient transport is a necessary condition for economic growth and improvement of living standards. Rural roads are critical to agriculture and mining, major sources of income in rural areas. For example, a better road lowers the cost of bringing inputs to producers and transporting outputs to markets. Lower input costs and higher farm-gate prices lead to higher outputs. Workers can access employment at lower generalised costs of travel, so wages net of transport costs rise and more people are willing to enter the labour market. Costs incurred by customers in accessing goods and services fall, and consumption levels are higher (Laird & Mackie 2014, p. 93).

Good roads can increase use of preventative healthcare services, which can lead to better management of health issues with better outcomes for individuals and savings in costs for governments. Good roads can support greater attendance at education facilities from early childhood to tertiary. There is abundant evidence for the returns of education in the form of higher lifetime earnings as well as a range of other benefits. Good roads help emergency services such as ambulances, fire engines and police vehicles provide more timely assistance when needed.

Some of the themes in the report, specifically improving access to education, health and employment though better roads, and of equitable road provision, are relevant to the Closing the Gap strategy. The National Agreement on Closing the Gap, which took effect in July 2020, aims 'to overcome the entrenched inequality faced by too many Aboriginal and Torres Strait Islander people so that their life outcomes are equal to all Australians'. Proportions of First Nations people are much higher in remote and regional areas and, on many indicators, the gap is greater in remote and regional areas compared with major cities.

While better roads can contribute to improved economic and social outcomes, they can only do so much. They do not add to the quantity or quality of services available in remote and regional areas. Expenditure on a given road has diminishing returns in terms of the impact on travel times and costs to road users. Once vehicles can travel at the standard maximum speed limit outside built-up areas in safety with minimal interaction with other vehicles, further improvements will be of no value. It is therefore essential to have systems in place that manage road spending taking into account competing objectives.

If investing in remote and regional roads beyond economically efficient levels is to be justified by social or equity objectives, the question ought to be asked whether road improvement is the most cost-effective way to achieve those objectives. For example, if the aim were to redistribute income to rural residents, it would be better to do it through the tax and social security systems. That would avoid wasteful spending to upgrade roads with low traffic levels and would give the beneficiaries the option to decide for themselves how to spend the funds. If the aim was to assist industries, direct subsidies or tax concessions might be better alternatives. Subsidising bus, rail or air transport can improve access in rural areas and benefit people who do not have access to vehicles, in particular, the elderly and youth. Access to education and healthcare might be more effectively improved by spending on the services themselves, for example, providing larger numbers of smaller, more geographically dispersed schools and hospitals. A concession on the fuel excise might reduce car operating costs more than the same amount spent on improving low-volume roads. However, decisions of this type need to be made at higher levels of government than the road agency.

1.4 Aims of the report

The report seeks to develop ways to improve the efficiency, equity and transparency with which decisions to invest beyond the levels supported by conventional CBA are taken, as well as clarifying the justifications.

The assessment methods developed in the report fall into 3 themes.

- estimation of social benefits from induced trips for the purposes of education, health and employment
- estimation wider economic benefits (WEBs)
- rationalising, deriving and applying equity weights.

The assessment methods under each of these themes can be implemented without the others if desired.

Social benefits and WEBs are economic efficiency benefits. Social benefits, as defined in this report, can occur where a road improvement induces people to make additional trips and people do not perceive the full value of those trips. WEBs arise from ‘imperfections’ in labour and product markets due to imperfect competition or taxes. For social benefits and the commonly occurring WEBs, the report provides methods and parameter values that CBA practitioners will be able to apply at their desktops using data already available from the CBA (traffic data, demand forecasts, transport cost estimates) and from published sources. The same methods and parameter values are intended to be applicable across the board to all road projects within set boundaries. It is acknowledged that the benefits estimated using these simple methods will be highly approximate.

Relevant concepts of equity from the literature are explored leading to a recommendation for a system of weighting benefits in CBAs with the weights derived from accessibility measures. The equity weights approach transforms CBA results from aligning with the efficient standards line to the equitable standards line in Figure 1.1, with tapering of the amount of economic efficiency sacrificed for equity as traffic volumes and standards rise. The discussion of distributional equity in the report draws on literature from the philosophy, economics and transport planning disciplines, demonstrating that the proposed equity weighting system is not an ad hoc solution, but has a robust pedigree in academic thought. It therefore deserves consideration by economists who have traditionally been reluctant to apply distributional weights in CBAs.

Equity weighting fits within the ‘adjusted CBA’ technique in the ATAP (2022a T2) CBA guideline. One of the adjustments to CBAs discussed is distributional weights, whereby benefits accruing to different groups of people in society are given different weights.

> The adjusted CBA methodology is a formal way to re-weight or incorporate non-efficiency objectives. Adjusted CBA is a hybrid of multi-criteria analysis and CBA, retaining the monetary measuring rod of CBA. Adjusted CBA is not an essential component of the methodology established by the Guidelines, but it is included as an option. The decision to use adjusted CBA should be made by the government agency responsible for developing the investment program, not by proponents of initiatives. All initiatives being compared must be subjected to the same adjustments. Therefore, it is the agency’s responsibility to decide which adjustments should be made and to decide the weights. (ATAP 2022a T2, chapter 12)

1.5 Structure of the report

Chapter 2 presents scene-setting information on how CBA estimates benefits of road projects, including equity issues, and on relevant aspects of road economics. Some components of the model of road investment in Chapter 7 are introduced, including the relationship between road spending and road user costs, and the optimum condition for economic efficiency.

Chapter 3 introduces the accessibility measure used throughout the report. The CI serves 2 purposes: (1) to estimate induced trips from which to calculate social benefits, and (2) to derive equity weights for benefits accruing to trips according to the remoteness of the location. CI data for remote and regional Australia is analysed.

Chapter 4 concerns 'social benefits'. They are economic efficiency benefits that arise from market imperfections in the form of beneficiaries under-perceiving the full value to themselves and society of additional trips. Unit values of benefits per trip are estimated for education, healthcare and employment trips for use in CBAs.

Chapter 5 considers possible WEBs that might arise for remote and regional road improvements. They too are economic efficiency benefits but are from imperfections in labour and product markets. Some of these are easy to estimate in CBAs, but others will be less common and much more informationally demanding to justify and estimate.

Chapter 6 examines theories of equity and distributive justice from literature in the disciplines of philosophy, economics and transport planning. The aim is to find a justification for investing in roads in remote and regional areas beyond economically efficient levels and a way to combine equity and efficiency in decision-making. The transport planning literature argues that consideration of equity in transport should focus on accessibility. The recommended approach stemming from the literature review is to apply to benefits in CBAs equity weights related to our CI.

Chapter 7 develops a model to explore some of the implications of equity weights, and proposes functional forms for calculating the weights from CIs.

Chapter 8 discusses matters that will arise if the methods in the report are implemented. These include calibrating the equity weighting function and a recommendation that practitioners applying the methods include a narrative in their CBA reports explaining why the claimed benefits are likely to be realised in the context of the project being appraised.

Appendix A contains literature reviews supporting the social benefit estimation in Chapter 4 in the areas of education and healthcare.

Appendix B contains 2 worked examples of application of the social benefits and equity weighting methods.

Appendix C contains details on the data sources and analysis undertaken by KPMG (2025) to derive the CIs.

2. Economic foundations

2.1 Introduction

The approach proposed in this report for assessing road improvements in remote and regional areas is based on the traditional social CBA methodology, but extends it to cover additional benefits, and to combine it with consideration of equity. This chapter provides background material for the rest of the report.

The first part of the chapter outlines the welfare economics basis of CBA. The aims are first, to clarify the relationship between economic efficiency and equity in the way CBA measures and aggregates impacts on individuals' wellbeing, and second, to introduce the idea of weighting benefits accruing to different beneficiaries. Economists have been reluctant to use distributional weights in CBAs, but they continue to be discussed in the literature. The distinction is made between utility weights, which counteract an inherent bias in the way CBA measures welfare changes, and equity weights, which reflect the moral or ethical judgements of decision-makers. The isoelastic function is introduced as a way to calculate utility weights. Later chapters of the report recommend use of equity weights and the isoelastic function is proposed as one way to calculate the weights.

The second part of the chapter introduces some relevant aspects of road economics. A model is developed whereby, as more is spent to improve a road, travel times fall, albeit with diminishing returns, benefiting road users. Economically optimal investment occurs where the benefit from spending an additional dollar on the road reaches one dollar. At this point, the BCR from additional spending is one. This model is used in Chapter 7 in the context of equity weights for CBAs of remote and regional road improvements.

2.2 How CBAs estimate benefits

2.2.1 Welfare economics basis

CBA is based on welfare economics, which may be defined as 'the study of the wellbeing of members of a society as a group, in so for as it is affected by the decisions and actions of its members and agencies concerning economic variables' Winch (1971, p. 13). Welfare economics is a part of 'normative economics', which makes statements about what 'ought to be' or 'should be', as opposed to 'positive economics', which is solely concerned about 'what is'. To make a statement about what 'should be' is to make a value judgement. It is an opinion based on a person's principles and beliefs, not a fact that can be checked or proved.

Nineteenth-century utilitarian philosophers and economists considered that a person's happiness, satisfaction or 'utility' could be measured on a scale via observation or judgement. Utility was considered to be a cardinal metric and that comparisons of utility levels could be made between persons. Famous economists in this category — the old welfare economics — included Edgeworth, Marshall and Pigou. The new welfare economics based on the work of Pareto, Kaldor, Hicks, and Scitovsky holds that the utilities of different persons cannot be compared, that is, interpersonal utility comparisons are ruled out. Cardinal utility was replaced with ordinal utility. Ordinal utility only allows bundles of goods to be ranked in order of preference. Welfare changes for individuals are compared using a money metric, that is, how much individuals would be willing to pay or accept to have one bundle of goods rather than another.

The value judgement of Pareto (the Pareto criterion) is that an improvement in social welfare occurs where one or more people are made better off without making anyone else worse off. A Pareto improvement, gauged using a money metric, is said to improve economic efficiency. Maximum economic efficiency or a Pareto optimum occurs where no further Pareto improvements can be made. 'Better off' and 'worse off' are in the eyes of the individual concerned, hence there is an implicit value judgement that an individual is the best judge of their own welfare, or 'consumer sovereignty'.

The Pareto criterion does not allow for comparisons between situations where there are losers as well as gainers, which is the case for virtually all policy changes. The less restrictive Kaldor-Hicks compensation criterion asks whether the gainers from a change could compensate the losers out of their gains and still have something left over. In other words, it asks whether a Pareto improvement could *potentially* occur. Compensation of the losers by the gainers would be necessary to convert a potential Pareto improvement into an actual Pareto improvement. Such compensation is hypothetical.[6]

Social CBA implements the Kaldor-Hicks compensation test by expressing as many of the benefits and costs as possible of a project or policy in a common unit, money, and adding them together. If combined benefits minus costs is positive, then the project or policy can be considered desirable and an economically efficient use of resources.

A CBA is always a comparison between 2 states of the world — a 'base case', where the project or policy is not implemented, and a 'project case' where it is (ATAP 2022a T2).

2.2.2 Welfare change measures

CBA measures benefits to consumers by assessing their willingness-to-pay (WTP) for a change. In the theoretical model of a consumer, utility is a function of the goods that an individual consumes, $U = U(\boldsymbol{q})$, where $\boldsymbol{q}$ is a vector of quantities. The consumer maximises this subject to a budget constraint, $y = \boldsymbol{p}.\boldsymbol{q}$ where *y* is income and $\boldsymbol{p}$ a vector of prices. The consumer's optimum consumption bundle is found where the condition is met that $\frac{MU_x}{p_x} = MU_y \; \forall \; x$ where $MU_x = \frac{\partial U}{\partial q_x}$ is the marginal utility of good *x*, and $MU_y = \frac{\partial U}{\partial q_y}$ is the marginal utility of income, that is, the increase in utility to the consumer from relaxing the budget constraint by one dollar.

Substituting the optimum condition for each good into the budget constraint equation, the Marshallian demand curve for an individual consumer for each good can be derived. Separating out good *a* from the rest, the demand curve, $q_a = q_a(p_a, \boldsymbol{p}, y,)$, relates the quantity consumed of good *a* to the price of good *a*, holding constant the prices of all other goods, $\boldsymbol{p}$, and the consumer's income level *y*. Substituting the demand curves into the utility function, the indirect utility function can be obtained, $V = V(p_a, \boldsymbol{p}, y)$, which expresses utility as a function of income and prices, with the consumer choosing their utility-maximising bundle of goods.

Say a project being appraised via a CBA leads to an increase in p_a. Utility for the individual would then fall.

- The 'compensating variation' is the increase in income, *y*, we need to give the individual *after* the price increase to restore the individual's utility to its base-case level. In the case of a price decrease, the compensating variation is the income taken from an individual to reduce their utility to the base-case level. The compensating variation is evaluated at project-case prices.
- The 'equivalent variation' is the income we need to take from the individual *before* the price increase to reduce their utility to the project-case level. In the case of a price decrease, the equivalent variation is the income given to the individual to raise their utility to its project case level. The equivalent variation is evaluated at base-case prices.

The 2 welfare change measures will not give the same result because the marginal utility of income is different when taking income from someone as opposed to giving them additional income. For a price increase for a 'normal good' (positive income elasticity), the compensating variation exceeds the equivalent variation, and conversely for a price decrease.

The compensating and equivalent variations can be measured as using Hicksian or compensated demand curves, which hold utility constant by compensating the consumer for their loss of purchasing power as price rises. The variation is the area between the Hicksian demand curve and the price axis over the price change.

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6 Scitovski added a second criterion to the Kaldor-Hicks compensation criterion, that a change should only be considered desirable if, after it has occurred, the losers could not compensate the gainers for a return to the original position. The paradox that, after a change is found to be desirable according to the Kaldor-Hicks compensation criterion, the reverse change can also be desirable, arises from distributional effects causing changes in relative prices. In practice, the possibility can nearly always be ignored because it would require a very large project with widespread economic impacts to cause the significant changes necessary.

As Hicksian demand curves are not observed, welfare changes are instead measured using consumers' surplus changes. The consumers' surplus change is measured using a Marshallian or uncompensated demand curve. A further justification for use of the consumers' surplus measure is that the income effects of a transport project will usually be small given the small to moderate share of transport expenditures in consumers' budgets (de Jong et al. 2007, p. 878).

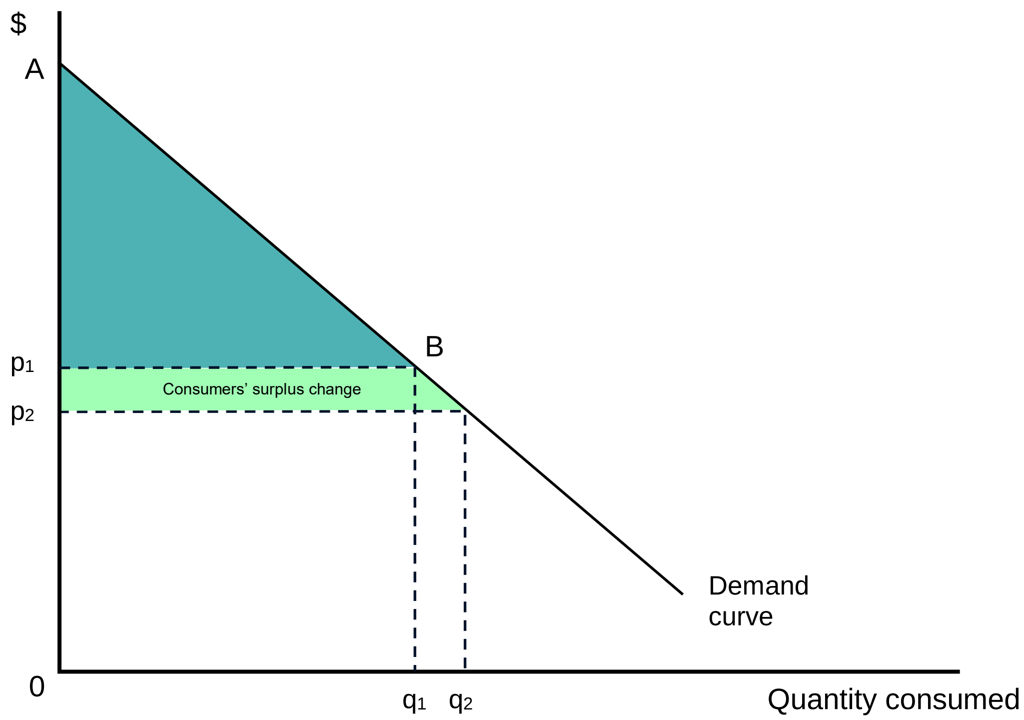
The Marshallian demand curve for a good *a* can be derived from the indirect utility function using Roy's Identity,

$$q_a(p_a, \boldsymbol{p}, y) = -\frac{\dfrac{\partial V(p_a, \boldsymbol{p}, y)}{\partial p_a}}{\dfrac{\partial V(p_a, \boldsymbol{p}, y)}{\partial y}}$$

The denominator is the marginal utility of income, MU_y. If a one-dollar price reduction caused a consumer to gain 200 utility units (the numerator) and their marginal utility of income was 2 utility units per dollar (the denominator), that implies they must be consuming 100 units of the good.

In Figure 2.1, WTP for a good sold at price, p_1, is the total area under the Marshallian demand curve between zero and the quantity consumed, $0ABq_1$. It is the maximum amount a consumer would be willing to give up to have q_1 rather than do without the good altogether. It is assumed that spending on the good is only a small proportion of their total budget, so income effects (changes in MU_y) are negligible. The total consumers' surplus is WTP minus what the consumer actually pays, $p_1 \times q_1$. The total consumers' surplus for the good is therefore the area under the demand curve extending upward from p_1, that is, p_1AB (the coloured triangle in Figure 2.1). For a reduction in price from p_1 to p_2, the consumers' surplus change is $-\frac{1}{2}(q_1 + q_2)(p_2 - p_1)$. This formula is known as the rule-of-half (ATAP 2022a T2). It is exact for a linear demand curve, as shown in Figure 2.1, and approximate for a non-linear demand curve provided the price change is not too large. For a very small price change the consumers' surplus change could be approximated by $-q \cdot \Delta p$ or with calculus, $-q \cdot dp$. The negative sign is needed because a fall in price leads to a positive change in consumers' surplus, and conversely.

Figure 2.1 Consumers' surplus change



The consumers' surplus for good *a* with a price p_a^* can be written as

$$CS_a = \int_{p_a^*}^{\infty} q_a(p_a, \boldsymbol{p}, y) dp_a$$

Differentiating with respect to p_a^*

$$\frac{\partial CS_a}{\partial p_a^*} = -q_a(p_a, \boldsymbol{p}, y)$$

Hence, a one-dollar fall in price leads to a consumer's surplus increase equal to the quantity of the good, that is, one dollar for each unit of the good consumed. The consumer who consumed 100 units per year would be $100 better off as a result of a one-dollar price reduction. For small changes in price and quantity, the triangular consumers' surplus area above q_1q_2 can be considered to be of negligible size.

Combining this last result with Roy's Identity,

$$\frac{\partial CS_a}{\partial p_a^*} = -q_a(p_a, \boldsymbol{p}, y) = \frac{\frac{\partial V(p_a, \boldsymbol{p}, y)}{\partial p_a}}{\frac{\partial V(p_a, \boldsymbol{p}, y)}{\partial y}} = \frac{\frac{\partial V}{\partial p_a}}{MU_y}$$

Since the prices of all other goods and income are held constant, we can write

$$dCS_a = \frac{\frac{\partial V}{\partial p_a}}{MU_y} dp_a$$

The consumers' surplus change for small change in the price of good *a* of dp_a is the change in utility, $\frac{\partial V}{\partial p_a}$, monetised by dividing it by the marginal utility of income.

While this is a practical approach where interpersonal comparisons of utility are ruled out, it has the effect of weighting peoples' utility changes by the reciprocal of their marginal utility of income, $1/MU_y$.

Summing the consumers' surplus changes over all individuals, *i*, in the population from a change in the price of good *a*,

$$\sum_i dCS_{ai} = \left(\sum_i \frac{\frac{\partial V_i}{\partial p_a}}{MU_{yi}} \right) dp_a$$

If the marginal utility of income decreases as income rises, consistent with economic theory, the gains and losses of utility for higher income individuals, having lower marginal utilities of income, will be given a greater weight than for lower-income individuals with higher marginal utilities of income.[7] Thus, CBA is biased against the poor because each dollar of benefit generates more welfare (increase in utility) for a poor person than for a wealthy person (Acland and Greenberg 2023a, p. 73). It would be possible for a project that primarily benefitted the poor to fail the CBA test, but still lead to a greater net utility increase summing over all members of society. Conversely, a project that mainly benefitted the well-off could pass the CBA test, but lead to a reduction of total utility.

2.2.3 **Utility weighting**

To correct the bias introduced by monetisation of changes in utility, application of weights that vary inversely with marginal utility of income has been proposed. The standard assumption is that the relationship between individual utility and income can be represented by an isoelastic utility function

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7 For a formal derivation of this result, see Negishi (1960).

$$U(y) = \frac{y^{1-\eta} - 1}{1 - \eta} \quad \text{if } \eta \neq 1\text{, and} \quad U(y) = ln\, y \quad \text{if } \eta = 1$$

Given this function, the marginal utility of income is $\frac{dU}{dy} = \frac{1}{y^{\eta}}$. The elasticity of marginal utility with respect to income is η. Setting the weight for the median income (y_m) at one, the 'utility weight' to place on the WTP for group *i* with income y_i is

$$w_i = \frac{dU}{dy_i} \bigg/ \frac{dU}{dy_m} = \frac{MU_i}{MU_m} = \left(\frac{y_m}{y_i}\right)^{\eta}$$

From a meta-analysis of 158 studies, Acland and Greenberg (2023b) recommended an elasticity of 1.61 with a 95% confidence interval of 1.18 and 2.04.

Introducing utility weights into CBAs is seen as a way to take explicit account of equity in relation to the distribution of income (see for example Squire & van der Tak 1975; Perkins 1994; Boardman et al. 2018). It represents a return to the old welfare economics and utilitarianism (discussed in Chapter 6), which seeks to maximise the sum of individual utilities. However, a utility-weighted CBA can still support projects that favour the rich at the expense of the poor. While utilitarianism is sensitive to the distribution of income (due to the diminishing marginal utility of income), it does not take account of the distribution of utility itself. To further shift the balance in favour of the poor, 'equity weights' could be applied on top of utility weights, as a second layer of weighting (Adler 2016).

For most road projects, the bulk of benefits are savings in travel time. According to TfNSW (2016, p. 241), travel time savings typically comprise around 60% and up to 80% of traditionally quantified benefits in CBAs of road projects.[8] Road users also benefit from savings in vehicle operating costs and crash costs. As travel time and crash risk do not have market prices, the unit values used in CBAs have to be obtained in other ways, typically from stated choice surveys. Survey respondents are asked to make hypothetical choices between travel on alternative routes with different characteristics in terms of cost, time and/or safety. A logit model is fitted to the survey data as follows. For the choice between routes *A* and *B* between the same origin–destination pair.

$$Probability\ of\ chosing\ route\ A = \frac{e^{V_A}}{e^{V_A} + e^{V_B}}$$

$$Probability\ of\ chosing\ route\ B = \frac{e^{V_B}}{e^{V_A} + e^{V_B}}$$

where V_A and V_B are the utility levels for each route and

$$V = \beta_c \times trip\ cost + \beta_t \times trip\ time + \beta_s \times probability\ of\ a\ crash$$

where the betas are coefficients (all negative, because higher costs, time and crash risk reduce utility). The value of travel time savings (VTTS), or the WTP to save an hour of time is

$$VTTS = \frac{MU_t}{MU_c} = \frac{\frac{\partial V}{\partial t}}{\frac{\partial V}{\partial c}} = \frac{\beta_t}{\beta_c}$$

Similarly, the WTP to avoid a crash is β_s/β_c. The coefficient for trip cost, being the utility change associated with an additional dollar of spending, is negative the marginal utility of income. So, in common with goods having market prices, the monetary value of an hour of time or a crash is given by the change in utility divided by the marginal utility of income.

Different WTP values for travel time and safety could be estimated for different income levels — higher values for groups with higher incomes, and conversely. Application of CBA to maximise the economic efficiency objective would apply different values to people with different incomes. However, virtually all transport CBAs

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8 Time costs include the costs of employing drivers of freight vehicles.

use ‘equity values’ of time and safety based on an average income level (Van Wee 2012, p. 4). This approximates utility-weighting because it assumes that individuals with different incomes would express the same valuation if they had the same income (Acland and Greenberg 2023a, p. 88 citing Banzhaf 2011). An alternative approach would be to use values of time and safety that vary with income and then apply utility weights, though Acland and Greenberg (2023a, p. 88) suggest that this might produce very different results. The ATAP (2024, 2025) stated preference survey covering time, reliability and safety, found no statistically significant relationship between income and WTP for trips of up to 2 hours duration, so the issue of equity weighting does not arise.

For CBAs of road projects, utility weighting is only relevant for benefits from savings in vehicle operating costs, which are priced in markets. As vehicle operating cost benefits tend to be small relative to travel time benefits, the issue of utility weighting can be set aside for the remainder of the report. However, we return to the idea of equity weights using an isoelastic function in Chapters 6 and 7, there related to accessibility, not income.

2.3 Road economics

Use of roads by vehicles differs from consumption of most goods and services in a number of respects. With the exceptions of toll and private roads, there are no direct charges to use a road. Instead, users incur the time spent travelling, vehicle operating costs that include fuel taxes, registration and licences fees, and crash risk. As previously noted, travel time is the largest component of road user costs. For private car drivers and passengers, the time cost is forgone utility, expressed in money terms. For business car drivers and passengers and commercial vehicles, the time cost comprises wages, the capital costs of vehicles, and the time cost for freight.

To set up a system that supplies roads at economically efficient levels under commercial arrangements is near impossible. Roads are natural monopolies, so prices need to be regulated to prevent over-charging. This is also the case for other network industries such as telecommunications, electricity and pipelines. But what makes roads different is that, while the range of acceptable quality levels for other network industries is a fairly narrow band, for roads, there is a huge range of quality levels appropriate for different parts of the network, ranging from dirt tracks to multilane freeways. Economic theory shows that a profit-maximising monopolist subject to price regulation, will underprovide on service quality (Harvey 2015). For other network industries, regulators can set minimum quality standards. For roads, the regulator would need to determine the standard for each individual part of the network as well as the price.

A further complication is that for most of the road system, the most economically efficient price is zero. Economically efficient prices are at the level of marginal social costs. For congested roads, which occur in urban areas, marginal cost pricing requires time- and location-specific charges set at the external cost each road user imposes on other road users (congestion charging). The Mohring-Hartwitz theorem shows that, provided there are constant costs in infrastructure provision, optimal congestion charges lead to exact cost recovery. Costs are roughly constant in urban areas because the economies of scale in road provision are approximately negated by the increasing costs of adding capacity in dense cities (Verhoef & Mohring 2009). For non-urban roads there are no offsets to the economies of scale, which causes economically optimal prices to fall well short of cost recovery. There is little or no congestion on most roads and cars do negligible damage to paved roads. Trucks do some damage to road pavements, but the economies of scale in pavement strength are so large that the revenue raised from charging for damage by trucks at marginal cost would fall well short of the total cost of road provision.

With commercial criteria unable to regulate provision, economically optimal qualities of road provision need to be determined using CBA.

2.3.1 Generalised cost

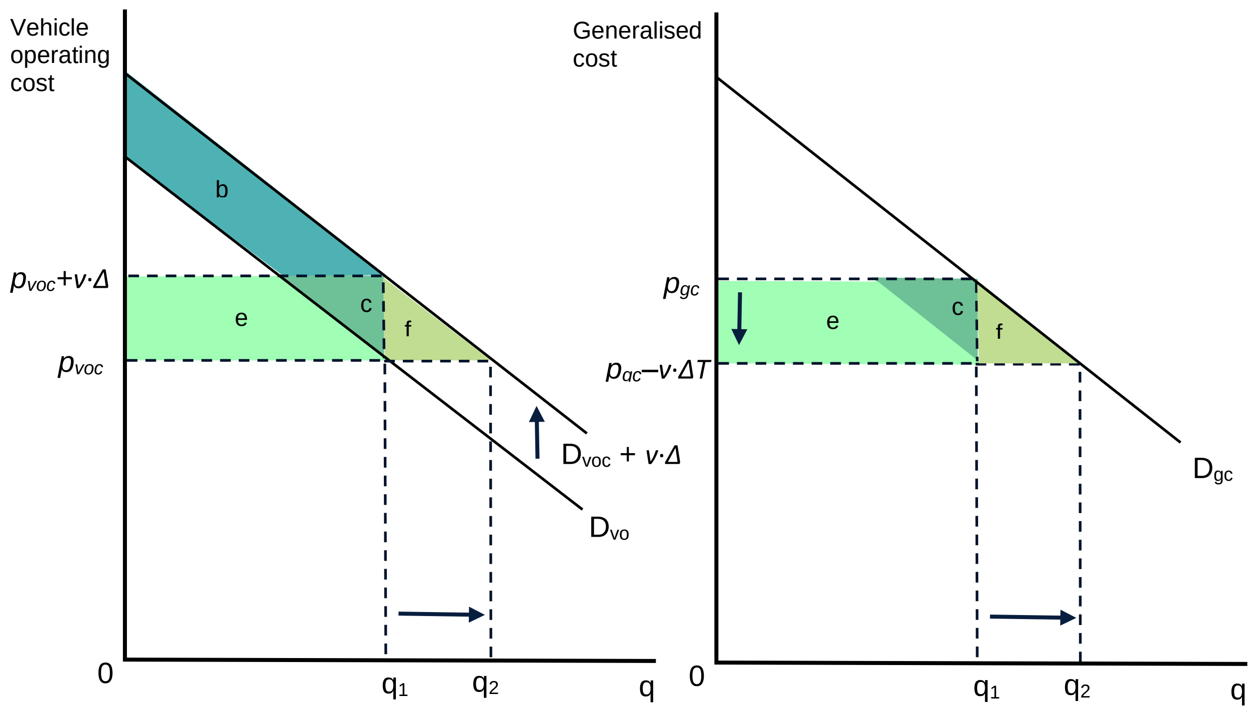
With the service quality aspects of road use — travel time, unreliability of travel times, and crash risk — being highly significant in relation to money costs, transport economists use the concept of ‘generalised cost’ in

CBAs and in discussions about road pricing. The generalised cost concept combines the money cost and service quality components of road use into a single measure.

The left panel of Figure 2.2 shows the demand curve for road use as D_{voc} as a function of vehicle operating cost in dollars. This is the way demand curves are represented for commodities in general, whereby quantity consumed is a function of price paid and product quality attributes are held constant. A road improvement that reduced travel time, with no change to vehicle operating costs, p_{voc}, will result in an upward shift of the demand curve by an amount $v \times \Delta T$, where v is the VTTS and ΔT is the time saved, reflecting higher WTP. The new demand curve is parallel to the old demand curve on the assumption that either all users have identical VTTSs, or users with different VTTSs are randomly distributed along the demand curve so the average value does not change along the demand curve. The quantity of traffic rises from q_1 to q_2. The consumers' surplus gain is the sum of areas *b*, *c* and *f*.

The right panel of figure 2.2 shows demand as a function of generalised cost, defined as the vehicle operating cost plus the time cost. A travel time saving worth $v \times \Delta T$ reduces the generalised cost p_{gc} by the amount $v \times \Delta T$. The quantity change is the same as in the left panel of the figure, from q_1 to q_2. The size of the consumers' surplus gain is also identical. However, the consumers' surplus gain is measured as the sum of areas *e*, *c* and *f*, noting that area *e* equals area *b*.

Figure 2.2 Explanation of generalised cost



For the remainder of this report, the generalised cost of travel on rural roads is taken to be just the travel time multiplied by the VTTS. This concentration on the largest component of generalised cost greatly simplifies the analysis. Accessibility, addressed in Chapter 3, is measured from travel times alone.

2.3.2 Economically efficient optimal investment

The generalised cost for a user of a specific length of road depends on the volume of traffic and the standard at which the road is provided. The term 'standard' is used throughout this report to cover the full range of road attributes that affect users including surface type, number of lanes, lane widths, shoulder widths, whether the shoulders are sealed, whether there is a median strip, curvature, gradient, safety barriers, signage, frequency and length of time of closure due to flooding, and road condition (roughness, rutting, potholing) (ATAP 2019 O5, p. 2). All of these factors affect travel times, vehicle operating costs, and safety. Environmental externalities are also included in CBAs, but tend to be small in relation to user costs, at least for non-urban roads.

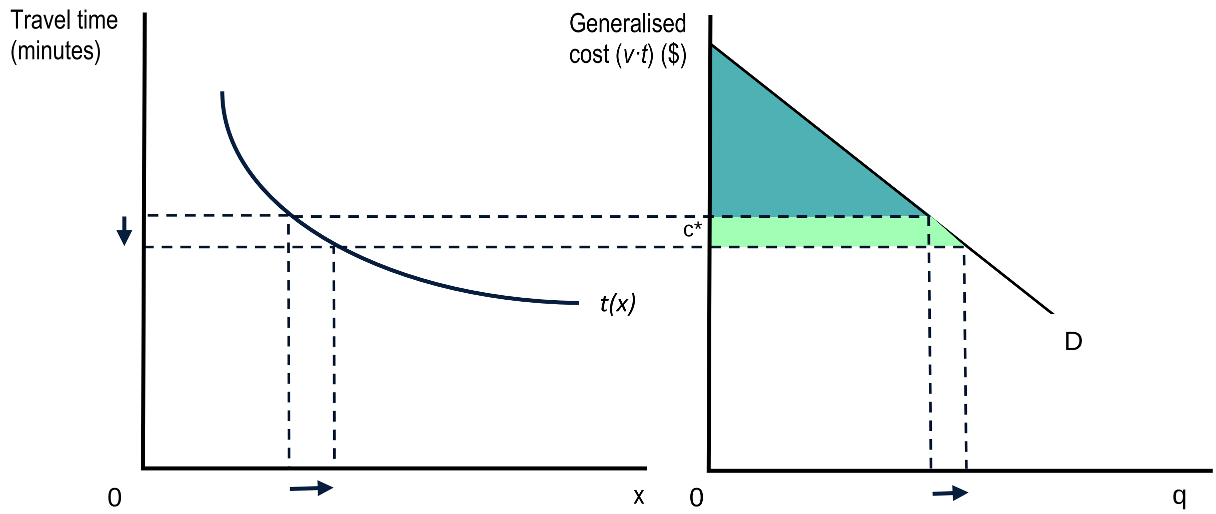
In this section and the model in Chapter 7, road standard is assumed to be perfectly divisible and the capital tied up in a road to be malleable. Such assumptions are common in theoretical models of road economics despite the existence of indivisibilities or lumpiness in investment in individual roads (for example, that the number of lanes must be an integer). In the long-run, road designers have considerable flexibility to vary capacity. Above the minimum width necessary for vehicles to pass, lane capacity can be varied by altering width and alignment. Overtaking lanes can provide intermediate capacity levels between 2 lanes and 4 lanes. For full networks, the effects of indivisibilities or lumpiness for individual roads would be lessened by pooling costs and benefits across road segments. Pooling would also occur over time as demand grows (Verhoef & Mohring 2009).

The theoretical models in Chapter 7 employ a relationship between travel time for road users and expenditure on the road, *x*. The expenditure measure, *x*, is the annuitised present value of capital and maintenance costs over the life of the road asset. If PV_{road} is the present value of the costs of providing the road over its economic life of *n* years discounted using a discount rate, *r*, the annuitised expenditure is

$$x = PV_{road}\left[\frac{r}{1-(1+r)^{-n}}\right]$$

Most of the costs of providing a single road segment are lumpy over time, with a construction cost for each upgrade and periodic maintenance costs. Only the routine maintenance costs are fairly constant from year to year. Taking the present value and converting it to an annuity smooths out the lumpiness.

Figure 2.3 Time and cost to traverse a road segment as a function of expenditure on the road



The left panel of Figure 2.3 shows how travel time over a length of road falls as more is spent on the road (assuming perfect divisibility), making the road wider, straighter and smoother which allows travel at higher speeds and in greater safety. There are diminishing returns in the relationship so that the curve eventually becomes flat when drivers can travel at the standard maximum speed limit outside built-up areas in safety with minimal interaction with other vehicles. As there are multiple ways in which funds can be spent to improve a road (widening, smoothing, realigning), the curve is drawn under an assumption that each additional dollar is spent in the way that engenders the maximum achievable travel time saving benefit to road users. As shown in Figure 2.3, travel time is represented as a continuous, decreasing, convex function of spending on the road, $t(x)$, with $t'(x) \leq 0$. The diminishing returns characteristic of the relationship means that $t''(x) \geq 0$.

Spending more on a road, shown on the left panel of Figure 2.3, leads to a reduction in travel time and hence in generalised cost, shown on the right panel of Figure 2.3, with the vertical axis scaled accordingly. The resultant consumers' surplus gain is indicated by the coloured band.

Optimal investment in road infrastructure occurs where the benefit from a further small increase in investment in road standards equals the marginal cost of that increase. In other words, the BCR of further improvement to the road equals one.

The consumers' surplus area for road use is the area under the demand curve, *q(c)*, where *c* is generalised cost, above the prevailing level of generalised cost, *c** (the coloured triangle in the right panel of Figure 2.3). It can be written as

$$CS = \int_{c^*}^{\infty} q(c)dc$$

as was done above in Section 2.2.2. CBA seeks to maximise the value to road users given by the total consumers' surplus area minus the cost of providing the road, *x*. It is assumed there are no taxes or changes on road use so gains and losses to governments related to road use can be ignored. The social welfare function (SWF) to be maximised is

$$W = CS - x = \int_{c^*}^{\infty} q(c)dc - x$$

Differentiating with respect to *x*, and setting the result to zero, the optimum investment condition is

$$\frac{dW}{dx} = -q \cdot \frac{dc}{dx} - 1 = 0$$

The generalised cost is assumed to be the VTTS, *v*, multiplied by the time taken *t*, that is, $c = v \cdot t$, so $\frac{dc}{dx} = v \cdot \frac{dt}{dx}$. The optimum investment condition can then be rewritten as

$$\frac{dW}{dx} = -q \cdot v \cdot \frac{dt}{dx} - 1 = 0$$

$$-q \cdot v \cdot \frac{dt}{dx} = 1$$

$$MBCR = 1$$

The left side of this expression is the consumers' surplus gain (*q·v·dt*) from an additional dollar of spending (*dx*) on the road. The negative sign is necessary because $\frac{dt}{dx} < 0$. It can be termed the marginal BCR (MBCR). The MBCR is the annual gain to society from investing an additional one dollar per annum in the road. For each dollar of road spending where the MBCR is above one, the gain to road users exceeds the cost. After spending passes the point where MBCR = 1, the gain to road users is less than the cost. When the flat part of the curve on the left panel of Figure 2.3 is reached, further improvements to the road are of no benefit to road users and the MBCR is zero.

The same principle applies to road maintenance. Optimal road maintenance spending is usually treated as a cost minimisation problem rather than a welfare maximisation problem. The reason is that, for a single segment of road considered in isolation, the induced traffic effects from changes to maintenance standards over the relevant range are likely to be small, and this assumption greatly simplifies the analysis. Determination of economically optimal spending on road maintenance involves finding the combination of treatment types (reseal, resurface, rehabilitation), and times at which to implement those treatments, that minimises the sum of the present value of road agency costs and the present value of road user costs over a long period of time into the future. For a given road segment, less frequent periodic maintenance treatments (resurfacing, rehabilitations) will allow the pavement to reach higher roughness levels before treatment. Road users will experience higher costs from driving on rougher roads. The MBCR can be defined as the present value of the saving to road users from spending an additional present value of a dollar on road maintenance. At the optimum, the MBCR is one. (For further detail see BITRE 2023 and Harvey 2024.)

2.4 Conclusion

Systems of weighting project benefits in CBAs dependent on the income of the beneficiaries, with weights calculated using isoelastic functions, are designed to counter the bias against low income people introduced by the monetisation of project impacts. Recent literature terms these ‘utility weights’. The values of these utility weights should be determined by the relationship between utility and income, for which there are numerous econometric estimates. Utility weights have the effect of converting CBA to a utilitarian welfare calculus. However, they only address equity to a limited extent because the gainers from a project can be well-off and the losers poorly-off. To fully account for equity considerations in CBAs, this recent literature proposes equity weights, which would be applied on top of utility weights. Equity weights should be determined by the moral or ethical judgements of decision-makers.

For CBAs of road projects, in most cases, the majority of benefits comprise travel time savings. Travel time savings and safety benefits are typically valued according to WTP, and vary with income level. However, in practice, equity values of travel time and crash risk reduction are used, which has the same effect as utility weighting. Also, a recent Australian stated preference survey found no statistically significant relationship between income and WTP values travel time and safety. Utility weighting is not therefore an issue for further consideration in this report. Equity weighting is proposed in later chapters, based on accessibility, not income.

If road investments were perfectly divisible, the economically optimal investment level would occur where the MBCR is one. The basic model developed in this chapter is further developed in Chapter 7 where the equity weighting system pushes investment beyond the economically efficient level for areas with poor accessibility.

3. Accessibility

3.1 Introduction

The concept of accessibility has 2 roles in the methods proposed in this report for assessing remote and regional road improvements.

- Changes in accessibility are used to forecast additional trips from road improvements with which to estimate social benefits in CBAs.
- Equity weights, with which to adjust project benefits according to the remoteness of the beneficiaries, are inversely related to accessibility.

Access is perhaps best thought of as 'the ability to derive benefits from things' (Ribot & Peluso 2003, p 153). Accessibility is a complex term, which researchers and practitioners typically define from the standpoint of the field in which they work (Reoch & Thomson 2018). In common parlance, it refers to design of infrastructure and services to enable use by people with disabilities. In the transport planning context, accessibility refers to the ease with which individuals can reach desired activities or services based on the associated transport costs (Davidson & Davidson 1999, pp. 4-5), or 'the relationship between the location and supply and the location of clients, taking account of client transportation resources and travel time, distance and costs' (Reoch & Thomson 2018, p. 3). It combines the concept of 'mobility' — the ability to move from one place to another — with the value of reaching destinations in terms of the quality and the quantity of the destinations. Good accessibility is an objective of the transport system because it enhances people's quality of life by giving them a wider range of opportunities for working, learning, shopping, services, recreation, and socialising. A wider range of opportunities improves the chances of finding alternatives more suited to each individual, in other words, better matching. As transport costs people time and money, better accessibility leaves more time and money available for other purposes.

Poor accessibility is linked to the geographical dimension of 'social exclusion' (Di Ciommo & Shiftan 2017, p 143). In the broad sense of the term, social exclusion refers to

> the lack or denial of resources, rights, goods and services, and the inability to participate in the normal relationships and activities, available to the majority of people in a society, whether in economic, social, cultural or political arenas. It affects both the quality of life of individuals and the equity and cohesion of society as a whole. (Levitas et al., 2007. p. 9 quoted in Lucas 2012)

Van Wee & Geurs (2011, p. 359) defined social exclusion as occurring where 'some people or population groups are excluded from a certain minimum level of participation in location-based activities, in which they wish to participate.' Social exclusion involves a combined interaction of different social problems that can occur simultaneously or cumulatively over a person's lifetime (Lucas 2012). In other words, it is multi-dimensional. Inaccessibility of goods and services contributes to a feeling of not belonging (Rajé 2003).

Some consequences of poor accessibility related to transport are the inability to access key life-enhancing opportunities such as employment, education, health and their supporting social networks. They include reduced job search activities, job losses, missed health appointments, school truancies, lower post-16 educational participation, increased physical isolation in later life, missed cultural and family events including weddings and funerals, and less participation in leisure activities and sports, particularly competitive sports among young people, often played by teams in distant locations.

Accessibility has both a use value and an option value, in that having access to a wide range of jobs, shops, medical services and educational facilities has a value in itself even if actual use is not made of these destinations, because it increases the number of choices available and thus future options (Nahmias-Biran et al. 2017, p. 193). It therefore relates to both the amount of travel people undertake and equity in terms of the opportunities people have.

The task of developing and estimating the accessibility measures in this chapter was undertaken by consultants, KPMG (2025).

This chapter discusses some of the main accessibility measures used in practice, the measure chosen for this report for remote and regional Australia, calibration of the parameters for the measure, and analysis of the values obtained. It further proposes a method to forecast induced traffic.

3.2 Measuring accessibility

3.2.1 Isochronic measures

The most basic approach to measuring accessibility is the isochronic or cumulative opportunity measure. It counts the number of potential opportunities that can be reached within a set travel time or distance (El-Geneidy and Levinson 2006, p. 6). The boundary of the set travel time is an 'isochrone'. An example is the number of jobs reachable within a 30-minute commute. Other opportunities that might be counted include retail outlets, recreational facilities, educational facilities, healthcare providers, population and income.

The disadvantages of cumulative opportunity measures are, first, that the choice of boundary travel time is based on subjective judgement, and second, that all opportunities within the boundary are counted as equally valuable, while those outside the boundary, even by small amounts, are considered to have no value.

3.2.2 Decay-weighted measures

Empirical data, corroborated by traveller insights, suggest that the importance of a destination does not abruptly diminish if it is slightly more distant. Its relevance reduces progressively with increased distance or time (Sundquist et al., 2021, p. 16). Decay-weighted measures assign greater value to destinations close to the point of origin reflecting the fact that people prefer closer opportunities over more distant ones and are reluctant to travel long distances.

The gravity measure, introduced by Hansen (1959), is probably the most widely used decay-weighted approach. In its original formulation, the model is

$$A_i = \sum_j \frac{O_j}{T_{ij}^b}$$

where

- A_i is accessibility at origin zone i
- O_j is the number of opportunities at destination zone j
- T_{ij} is the impedance between zones i and j
- b is an exponent greater than one, reflecting increasing reluctance to travel longer distances.

A more general formulation uses an impedance function, $A_i = \sum_j O_j f\left(T_{ij}\right)$, where the impedance function $f\left(T_{ij}\right)$ could have the form $exp\left(\theta\, T_{ij}\right)$ where $\theta < 0$.

The number of opportunities indicates attractiveness or the desirability of making a trip to a particular destination. The number of jobs in a destination zone is often used to measure employment accessibility and population to measure social attractiveness (Grengs 2015). Numbers of education and health facilities could be used to measure access for those particular purposes.

Impedance quantifies the effort of reaching a destination. Measures include distance, travel time or generalised cost using a given transport mode, or straight-line distance, with travel time the most common.

3.2.3 Utility-based measure

The utility-based accessibility measure is derived from the random utility model for discrete choices by consumers. In common with decay-weighted measures, both the attractiveness of destinations (number of opportunities) and impedance (travel time or cost) are taken into account. Utility-based measures capture the valuation of accessibility by individuals (Geurs & Van Wee 2004, p 136). Consumers' surplus changes can be estimated by dividing a utility change by the marginal utility of income.

The utility obtained from choosing from alternative *j* is a function of the attributes of that alternative that the researcher can observe, such as money cost and time taken, V_j, and an unobserved random component, ε_j, arising from omitted attributes, measurement errors and random taste variations across individuals. So utility from alternative *j* can be decomposed into $U_j = V_j + \varepsilon_j$.

The probability that an individual will choose alternative *j* over alternative *k*, is

$$P_j = Prob(U_j > U_k) = Prob(V_j + \varepsilon_j > V_k + \varepsilon_k) = Prob(\varepsilon_k - \varepsilon_j < V_j - V_k)$$

If the unobserved part of utility, ε, for each alternative is assumed to be independent and identically Gumbel distributed, the logit model is obtained. The Gumbel distribution has a shape similar to the normal distribution. The independence assumption is that the unobserved portion of utility for one alternative is unrelated to the unobserved portion of utility for another alternative.

Representative utility is usually specified to be linear, $V_k = \boldsymbol{\beta}'\boldsymbol{x_k}$, where $\boldsymbol{x_k}$ is a vector of observed variables for alternative *k* and $\boldsymbol{\beta}$ is the vector of coefficients.[9] For multiple alternatives, the probability of choosing alternative *k* from a number of alternatives with subscript *j* is

$$P_k = \frac{e^{V_k}}{\sum_j e^{V_j}} = \frac{e^{\boldsymbol{\beta}'\boldsymbol{x_k}}}{\sum_k e^{\boldsymbol{\beta}'\boldsymbol{x_j}}}$$

This is the logit model, mentioned in Chapter 2 in the context of the value of travel time savings, which predicts the probability of an individual choosing one option among 2 or more alternatives.

The expected maximum utility gained by the individual choosing from a number of alternatives is the natural logarithm of the denominator, known as the 'logsum', that is,

$$U = ln\left(\sum_{\boldsymbol{j}} e^{\boldsymbol{\beta}'\boldsymbol{x_j}}\right)$$

Applying the model to accessibility, the individual at origin *i*, has to choose between alternative destinations. The probability that they will choose destination *k* is given by the logit model with travel impedance and the attractiveness of opportunities in each destination zone entering into the utility function as attributes. The probability can be interpreted as the proportion of people living in zone *i* that will travel to zone *k*. Attributes in the utility function that impede access would have negative coefficients and attractive attributes would have positive coefficients.

Either $\sum_j e^{V_j}$ or $ln\left(\sum_j e^{V_j}\right)$ could be used as the accessibility measure. Taking the logarithm does not change the ranking of accessibility scores when comparing different origins.

Where there is just one destination, the logsum reduces to $ln(e^{V_j}) = V_j$. So the logsum is an approximate weighted average of the utilities of all the alternative destinations.

The accessibility measure used throughout this report has the form

$$A_i = \sum_j e^{\lambda\, t_{ij} + \mu\, ln(P_j)} = \sum_j e^{\lambda\, t_{ij}} P_j^{\mu}$$

where

- A_i is the accessibility measure for origin zone *i*
- t_{ij} is travel time between origin *i* and destination *j*

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9 This exposition of the logit model is from ATAP (2022a T2, Appendix C), based on Train (2003).

- λ is the marginal utility of travel time, with $\lambda < 0$
- P_j is population at destination zone j indicating the number of opportunities at the zone or attractiveness
- μ is a coefficient that controls the marginal utility of the attractiveness of destination zones, with $\mu > 0$.

The advantage of taking the *log* of population in the utility function is that it allows simplification to $\sum_j e^{\lambda\, t_{ij}} P_j^{\mu}$. There is diminishing marginal utility with respect to destination zone size, the rate of which is controlled by the value of μ.

3.2.4 The ARIA+ measure

A leading accessibility measure for remote and regional Australia is the 'Accessibility and remoteness index of Australia plus' (ARIA+) (and also ARIA++) produced by the University of Adelaide and used by the Australian Bureau of Statistics (ABS). It is produced for over 12,000 populated localities with values ranging from zero (high accessibility) to 15 (high remoteness). The method of calculation is to

- classify destinations termed 'service centres' on a scale of 5 levels, A to E (6 levels A to F for ARIA++) based on the population at the service centre. Category A service centres have a population of over 250,000 persons and category E with a range from 1,000 to 4,900 persons.
- calculate the distance by road from each of the 12,000 populated localities to the boundary of the nearest service centre in each of the 5 categories (6 for ARIA++)
- divide each distance value by the Australian average for that category to derive a standardised ratio
- limit each ratio to a maximum value of 3 to remove any extreme values
- sum the 5 values (6 for ARIA++).

A location would have to have a ratio of 3 for all 5 service centre categories to obtain the maximum score of 15. For ARIA++, with the sixth category with 200 to 999 persons, the maximum score is 18.

An interpolation procedure is used to derive index values on a 1km grid so all locations in Australia have an index value.

For the following 4 reasons, ARIA+ was not considered suitable to meet the objectives of the present report where a relationship between road improvements and trips made is required:

- When transitioning between localities, the score can abruptly shift when the nearest service centre of any of the categories changes.
- Road improvements usually save travel time without affecting distance travelled, and so would have no effect on the ARIA+ score.
- The upper limit of 3 can make the ARIA+ insensitive to differences between very remote locations.
- Few trips would be made by residents to very distant service centres. For example, the national average distance for category A is 412km. The score is sensitive to distances to category A service centres up to 1,236km away.

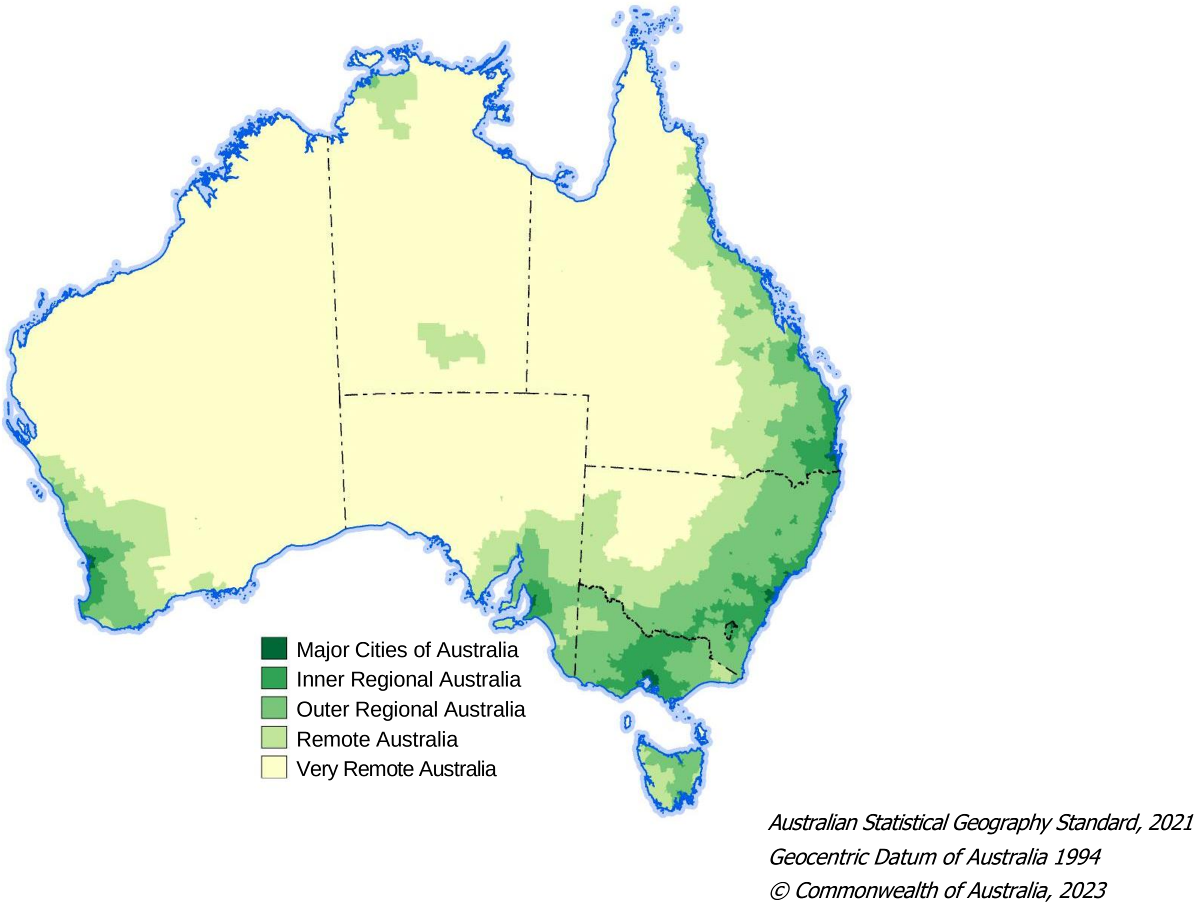
3.2.5 ABS Remoteness Area structure

The ABS uses ARIA+ for its Remoteness Area (RA) structure. There are 5 classes of remoteness based on average ARIA+ values for Statistical area 1s (SA1s) falling within the following ranges:

- Major Cities of Australia: 0 to 0.2
- Inner Regional Australia: > 0.2 and ≤ 2.4
- Outer Regional Australia: > 2.4 and ≤ 5.92
- Remote Australia: > 5.92 and ≤ 10.53
- Very Remote Australia: > 10.53

Anomalies are removed, such as a single SA1 that is not an Urban Centre and is completely surrounded by SA1s of a different remoteness class, is merged into the surrounding remoteness class. Figure 3.1 is a map of the RAs.

Figure 3.1 Australian statistical geography standard edition 3: Remoteness structure



Source: ABS

3.3 Connectivity index calibration

3.3.1 Connectivity index details

KPMG (2025) reviewed some remoteness indexes in the Australian literature in addition to those in the previous section. The utility-based measure was selected because it is sensitive to travel time improvements and has a rigorous theoretical basis. The logsum utility formulation fits neatly into the equity weighting approach in Chapter 7 that balances the marginal utility loss from increased road spending with the utility gains from higher standard roads. KPMG used the term 'connectivity index' (CI) for the recommended accessibility measure, terminology that has been adopted in this report.

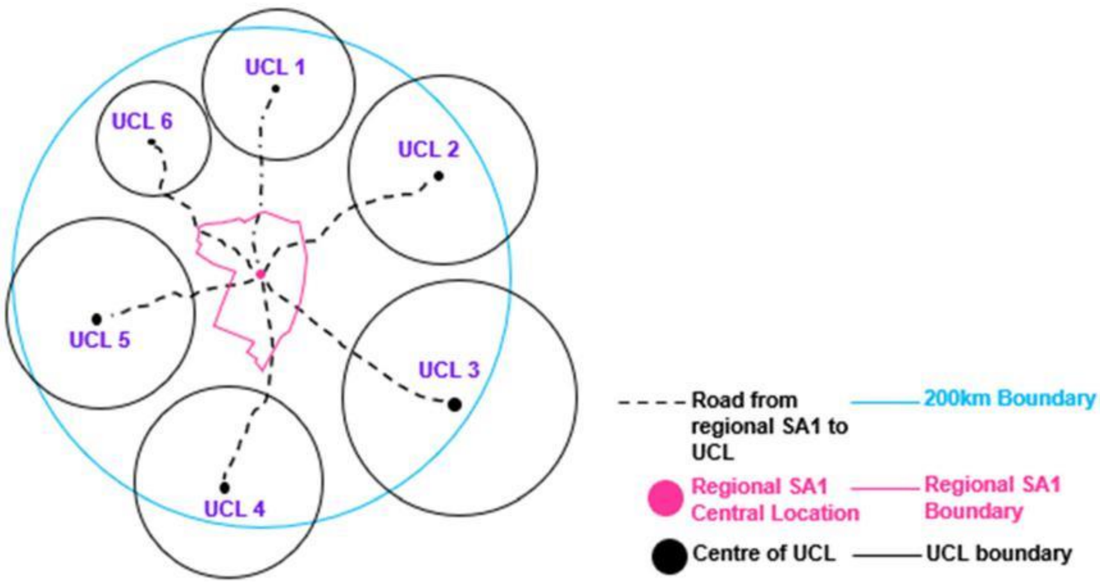
CI values were calculated using SA1s as origins. SA1s have a population of between 200 and 800 people with an average population size of approximately 400 people, with generally smaller populations in remote and regional areas. They are the building blocks for higher aggregations (SA2, SA3 and SA4), the Urban Centres and Localities (UCLs) and RA structures. They are designed to be predominantly rural or urban in character and to identify Aboriginal and Torres Strait Islander communities in remote areas.[10]

The CI uses UCLs as destinations or service centres, representing areas of concentrated urban development. ‘Urban centres’ comprise SA1s with threshold population densities. Adjacent urban SA1s are combined to form urban centres if the aggregated population of urban SA1s is 1,000 persons or more, or the combined urban SA1s have an urban identity, meaning shared urban facilities of some kind and an identifiable name. Discrete Aboriginal and Torres Strait Islander communities and discrete tourist resorts with a population exceeding 1,000 are considered to be Urban Centres regardless of density. Adjacent SA1s are combined to form ‘localities’ where the aggregate populations of urban SA1s is between 200 and 999 persons and they have some shared urban identity.[11]

KPMG (2025) identified 61,845 SA1 centroids (origins) and 1,837 UCL centroids (destinations) from ABS 2021 shapefiles after data cleaning. SA1 centroids were relocated to the nearest road within 40km because some centroid locations were inaccessible by car. Where an SA1 centroid was not located within 40km of the road network, the SA1 was excluded to ensure that a travel time by car could be calculated. The excluded SA1s were typically located in deserts in central Australia. As this report is focused on roads in remote and regional areas, SA1s in the Major Cities RA were excluded, leaving 19,088 SA1s in the database. SA1s located on islands not accessible by road were also excluded, leaving 18,861 SA1s.

The CI aims to measure access for trips people make on a regular basis for education, healthcare and employment purposes. Origin–destination pairs over 200km apart on a straight-line distance measure were removed on the grounds that people in remote and regional Australia would not be willing to travel to UCLs further away except on infrequent occasions. Hence, the CI for a given SA1 only takes into account destination UCLs with centroids within a circle with a 200km radius around the SA1 centroid. Where the closest UCL was more than 200km away, a CI value of zero was assigned, indicating extremely poor connectivity. The 200km restriction also reduces the number of origin–destination pairs to a manageable level. Figure 3.2 illustrates construction of the CI.

Figure 3.2 Illustration of construction of connectivity index



Source: KPMG (2025)

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10 Australian Bureau of Statistics Jul2021-Jun2026, Urban Centres and Localities, ABS, viewed 23 December 2024, https://www.abs.gov.au/statistics/standards/australian-statistical-geography-standard-asgs-edition-3/jul2021-jun2026

11 Ibid

A minimum travel time of 5 minutes was set as shorter trips are unlikely to be made by car. This addresses situations where the destination UCL centroid lies within the origin SA1 boundary.

3.3.2 **Connectivity index calibration**

The index had to be calibrated with suitable values for the rate at which accessibility declines with travel time, λ, and increases with destination population size, μ. Population data for the SA1s and UCLs were taken from ABS 2021 Census data and travel times by car from Open Street Map and Open Trip Planner. Details of the data sets, estimation of trips per day and regression analyses from KPMG (2025) are provided in Appendix C.

The parameter values in the CI and the relationship between trips and CI were estimated by regression analysis for each of the 3 trip types — education, health and employment. Trips *per person* per day originating in each SA1 was used as the dependent variable because *total* trips per day by all people in an SA1 would be highly correlated with the SA1 population size.

For the education trip purpose, trip numbers and the relevant populations were further sub-divided into early childhood, primary and secondary, and tertiary. Data on historical numbers of trips and relevant populations was obtained from the ABS, the Australian Curriculum, Assessment and Reporting Authority (ACARA), the Australian Government Department of Education (DE) and the Australian Institute of Health and Welfare (AIHW). The relevant populations were:

- childcare — persons aged 0 to 5
- primary and secondary education — persons aged 7 to 16
- tertiary education —persons aged 18 to 25[12]
- health — entire population
- employment — working age defined as persons aged 15 to 64.

For childcare and health, data related to trips per day was available only at the SA3 level and for primary and secondary education, at the level of RA by state or territory. Rates of trips per person per day for the relevant populations at the SA3 level or RA by state/territory were assumed apply to the relevant populations in all SA1s within each SA3 or state/territory-RA. For. Employment trips per person per day originating in each SA1 were estimated by dividing numbers of people who travelled to work by the working age resident population from the ABS 2016 Census data (pre-Covid-19).

Numbers of trips per day were checked by comparison with average annual daily traffic (AADT) level data obtained from state and territory road agencies.

Ordinary least squares regression analysis was employed with the control variables being:

- proportion of Indigenous population (to capture the employment, education and health gaps between Aboriginal and Torres Strait Islander people and the rest of the population)
- proportions of the working age population aged 15 to 24, 40 to 64 (reflecting increased likelihood of health conditions with age), with bachelor degrees, and with masters or higher degrees (reflecting socio-economic attributes of origin SA1s), and
- state dummy variables.

A range of other variables available from the census were considered but were excluded on the grounds that they could give rise to endogeneity. For example, the unemployment rate was omitted because it would be directly related to the number of employment trips. Variables related to income were omitted because a higher number of trips could generate additional income. Separate regressions were undertaken for the 5 trip categories, testing alternative model specifications (including linear–linear, log–linear, linear–log, log–log and non–linear) and with CI parameters ranging from –0.01 to –0.12 for λ and from 0.3 to 2.0 for μ. The choice of parameters was made considering 3 criteria

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12 Ages 6 and 17 were excluded on the grounds that they are borderline with the population split between the 2 adjacent categories.

- responsiveness — the change in the number of trips from a hypothetical travel time scenario in which there was a 10-minute travel time saving from 75 to 65 minutes for a destination UCL with a population of 50,000
- goodness of fit — the r-squared from the regression model
- positive and statistically significant coefficient for the CI variable.

In all 5 cases, the CI parameter values selected were those from linear–linear models that maximised responsiveness with confirmation that the sacrifice of modelling fit from not choosing the parameter value combination with the maximum r-squared was very small. Visual diagnostic tests were applied to check the suitability of the models.

Table 3.1 summarises the results of the 5 final regression models, including the recommended CI parameter values. All the CI coefficients were statistically significant at the 1% level. The confidence intervals are, at most, 30% above and below the coefficient estimates. The change in λ values from –0.06 for employment to –0.05 for education and –0.04 for health indicates increasing willingness to travel longer distances to access destinations for each respective trip purpose. Full-time employees would need to commute up to 5 days a week, while health trips would be much less frequent.

Table 3.1 Trips per person — connectivity index regression results summary

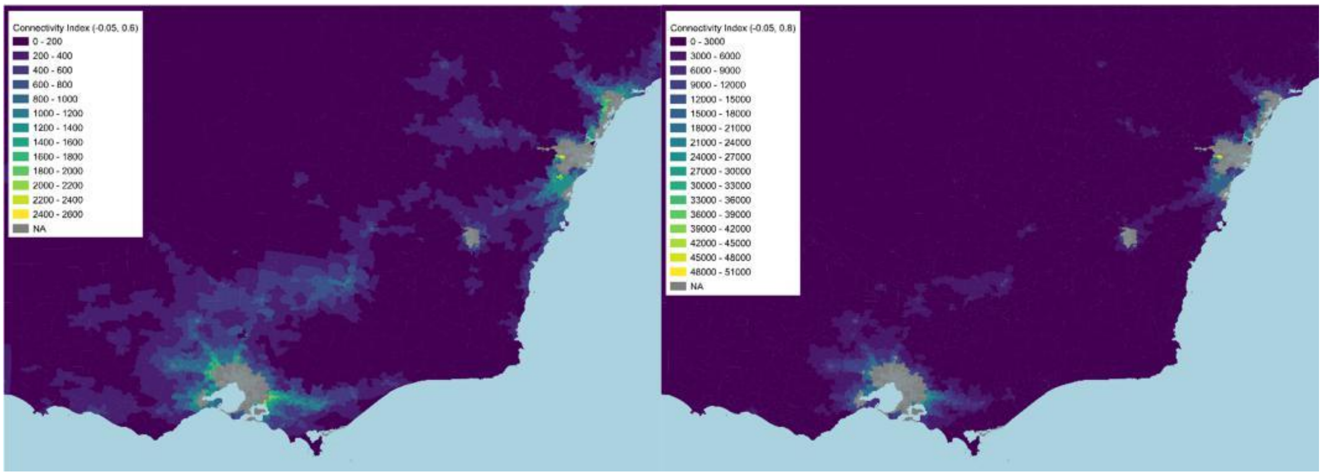
Trip type	Early childhood education	Primary and secondary education	Tertiary education	Health	Employment
Number of observations	18,716	18,888	9,970	18,880	17,675
R-squared	0.2787	0.5655	0.3290	0.4517	0.2834
CI parameter λ	–0.05	–0.05	–0.05	–0.04	–0.06
CI parameter μ	0.6	0.6	0.6	0.6	0.8
CI coefficient	103.69×10^{-6}	15.96×10^{-6}	64.91×10^{-6}	1.64×10^{-6}	1.88×10^{-6}
95% confidence interval: lower	99.16×10^{-6}	14.88×10^{-6}	55.44×10^{-6}	1.59×10^{-6}	1.31×10^{-6}
95% confidence interval: upper	108.22×10^{-6}	17.04×10^{-6}	74.37×10^{-6}	1.70×10^{-6}	2.45×10^{-6}

Source: KPMG (2025)

The higher μ value of 0.8 for employment compared with 0.6 for education and health might be due to the greater number of employment destinations outside UCLs, causing trip numbers to rise at a faster rate with respect to UCL populations, compared with education and health trips, which have destinations more concentrated in UCLs. Employment destinations would be more scattered outside UCLs, for example, farms, sheep and cattle stations, and mines. This might also explain the lower R-squared for employment.

Figure 3.3 illustrates the effect of differences in the μ values. The higher the value of μ, the more sensitive the CI is to the size of the service centres. A value of 0.8 suggests a steeper increase in utility as the size of the destination UCLs increases, resulting in a concentration of higher utility in peri-urban areas bordering major cities, as opposed to a value of 0.6 that suggests a more gradual change in utility as one moves away from the major service centres.

Figure 3.3 Effect of different μ values 0.6 and 0.8



Source: KPMG (2025)

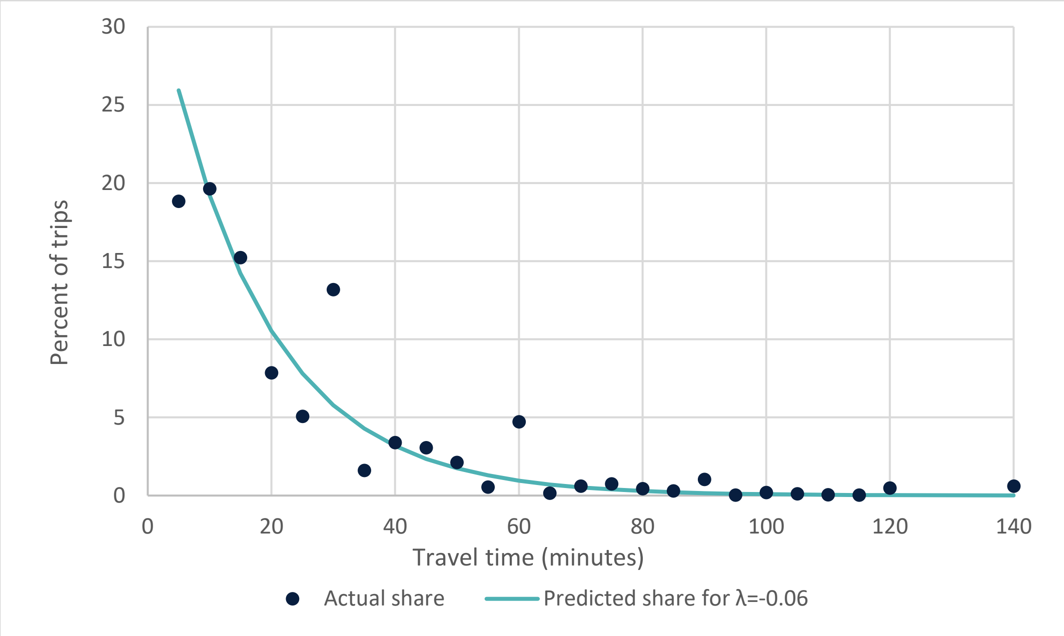
The coefficient estimates imply that an improvement of one unit in the CI will result in an increase in trips per person per day in a range of 1.64×10^{-6} to 103.69×10^{-6} for the relevant population as defined above. These relationships can be used to predict numbers of additional trips resulting from a road improvement. Note that all 3 CIs are calculated using *total populations in destination UCLs*. The trips per person per day estimate uses the *relevant population in the origin SA1*. Worked examples are provided in Section 3.5 and Appendix B.

The coefficient for travel time in the CI, λ, reflects the decline in peoples' willingness to undertake longer trips. In 1994, Cesare Marchetti, an Italian physicist, described an idea that has come to be known as the Marchetti Constant. In general, he declared, people in all societies have always been willing to commute for about a one hour a day on average, that is, a half hour commute in each direction (Marchetti 1994; Metz 2008). In 1994, The National Travel Survey for Great Britain showed people travel for an average of close to one hour per day (Metz 2004).

BITRE (2016) reported that the average one-way commuting time in Australia is 29 minutes. Nearly a quarter of commuters — more than 2 million people — travel for 45 minutes or more one way. Commutes longer than 45 minutes are perceived to reduce wellbeing. BITRE (2016, figure 3.4) plotted shares of employed individuals for discrete commuting trip durations in 5-minute intervals from 2012 HILDA data for the 5 major capitals combined and other locations combined. The average commuter time was 32.1 minutes for the 5 major capitals and 23.1 minutes for other locations (BITRE 2016, p. 38).

Figure 3.4 plots the shares from BITRE (2016) for average commuting trip durations for locations outside the 5 major capitals and overlays it with a curve for the predicted shares from the logit model with the employment CI parameter $\lambda = -0.06$ assuming a uniform destination population for all points. The predicted percentage share of trips for each of the 25 trip durations, i, from the logit model is $\frac{100 \cdot e^{\lambda t_{ij}} P_j^{\mu}}{\sum_{i=1}^{25} e^{\lambda t_{ij}} P_j^{\mu}}$. Assuming that the populations at all destinations are the same, the P_j^{μ} terms cancel out. The predicted shares were estimated for each of trip duration in Figure 3.4 from $\frac{100 \cdot e^{-0.06\, t_i}}{\sum_{i=1}^{25} e^{-0.06\, t_i}}$. To help distinguish between the 2 sets of points, the predicted shares are represented as a smooth curve. The figure suggests that the –0.06 value for λ is reasonable.

Figure 3.4 Actual and predicted shares of commuters outside major cities for different travel times



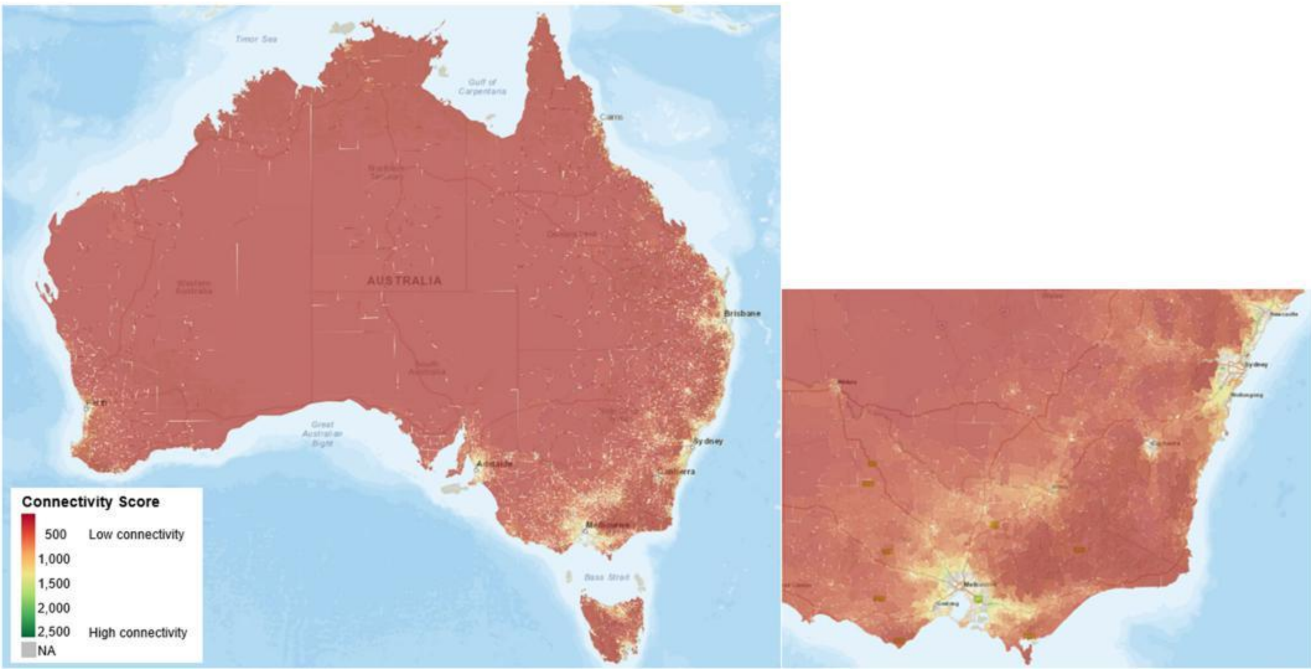
Note: The last observation from BITRE (2016, p. 38) was for 'more than 120 minutes.' This has been plotted as a travel time of 140 minutes.

3.4 Analysis of connectivity index data

This section examines the CI data estimated by KPMG for SA1s outside major cities as defined by the RA structure (see Section 3.2.5). As well as SA1s in major cities and islands without road access, SA1s with zero populations were excluded from the analysis. This resulted in a database of 18,491 SA1s. A small number of SA1s, 28, had CI of zero because there were no UCLs within the 200km radius of the SA1 centroids.

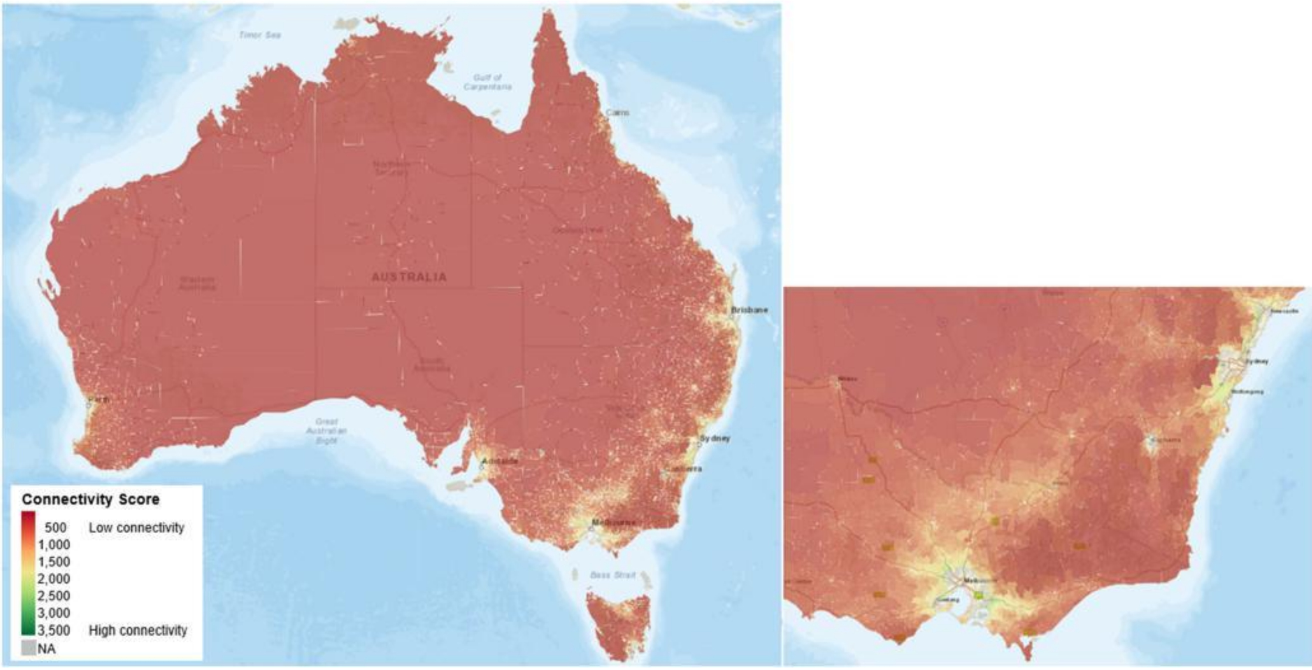
Figures 3.5, 3.6 and 3.7 show maps of the 3 CIs. The CIs for the 3 trip purposes are on different scales ranging from zero to a maximum 2,564 for education, 3,654 for health and 35,274 for employment.

Figure 3.5 Connectivity index map — education: λ = –0.05, μ = 0.6



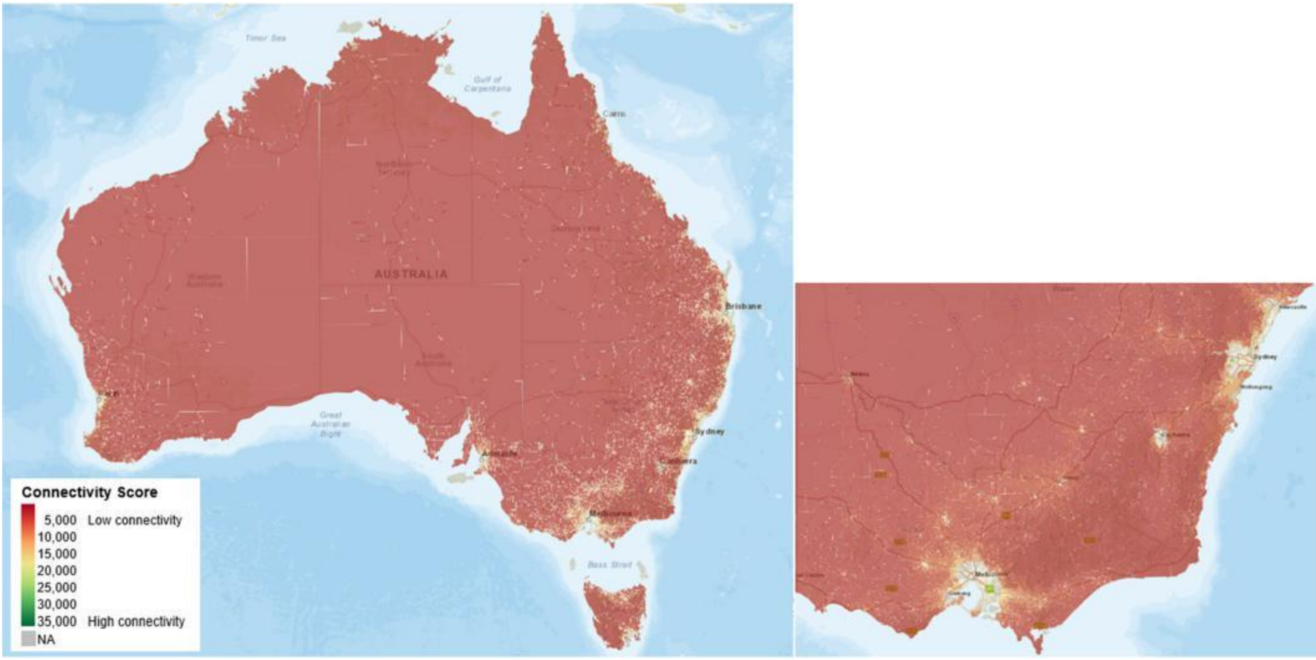
Source: KPMG (2025).

Figure 3.6 Connectivity index map — health: λ = –0.04, μ = 0.6



Source: KPMG (2025).

Figure 3.7 Connectivity index map — employment: *λ* = –0.06, *μ* = 0.8



Source: KPMG (2025).

Figure 3.8 shows the distributions of 4 variables over the range of the employment CI (λ = –0.06, μ = 0.8). Values for the employment CI range from zero to 35,274. Note that, in Figure 3.8, the intervals in index values increase from 500 to 1000 above 11,000. The 22 SA1s with index values above 16,000 were grouped together in the right-most bar of each chart.

The upper 2 panels show the combined population (from the 2021 Census) in the SA1s and the numbers of SA1s in each of the CI intervals. They indicate that the bulk of the population and SA1s outside major cities are in the lower end of the range. The picture would look very different if the highly connected SA1s in the Major Cities RA were included.

The lower panels provide information about the UCLs within a 200km radius of each SA1 centroid and hence used to calculate the CI. The sum of UCL populations and number of UCLs for each CI interval were averaged by dividing by the number of SA1s for the interval. The panels show how both UCL size and the number of relevant UCLs rise with the CI. The number of UCLs and total population of UCLs within a 200km radius are examples of isochronic or cumulative opportunity measures as discussed in Section 3.1.

The education (λ = –0.05, μ = 0.6) and health (λ = –0.04, μ = 0.6) CIs display similar patterns but over much smaller ranges, up to maximums of 2563 and 3654, respectively.

Figure 3.9 shows whisker plots, one panel for each CI type, for numbers of SA1s. In each panel, the leftmost whisker plot shows CIs for all SA1s in the data. The other 4 plots in each panel show the CIs for the SA1s grouped by ABS RA. As expected, average and median CI values decline with increasing remoteness but there is overlap between the accessibility measures for each RA. For all 4 RAs, the lowest CI is zero.

Tables 3.2 presents similar information showing the population-weighted average CI for the 4 ABS RA categories outside major cities. Also shown in Table 3.2 are the population-weighted numbers of UCLs and the average UCL population within a 200km radius of each SA1, used to calculate the CI illustrating how both the number and size of UCL destinations with a 200km radius decline with remoteness. Table 3.3 lists the maximum CI values by RA. Comparing with the average CIs in Table 3.2, it can be seen that, in all cases, the maximum CI for each RA category is well above the average of the category above. For example, in the case of the employment CI, the maximum value for the Very Remote category of 1,423 from Table 3.3, is well above the average for the Remote category of 717 from Table 3.2.

As noted in Section 3.2.5, the ABS RA structure is derived from ARIA+ index, which allows for much longer distances between origin and destination zones compared with our CI. Being limited to a 200km radius, our CI focuses on relatively short trips that are undertaken frequently — multiple times a week in the cases of employment and education. Another contributing factor would be the removal of anomalies by the ABS in setting the RA boundaries to avoid single SA1s being completely surrounded by SA1s of a different remoteness class.

Table 3.2 Population weighted average connectivity indexes by Remoteness Area

Remoteness Area	CI education	CI health	CI employment	Number of UCLs	UCL population size
Inner regional	700	1,016	3,987	143	3,004,433
Outer regional	355	463	2,189	62	528,564
Remote	135	162	717	21	121,509
Very remote	47	52	198	5	7,597
All	561	798	3,244	111	2,022,217

Notes: For each weighted average CI, the population weighted average is $\sum_i CI_i \times Pop_i / \sum_i Pop_i$ where Pop_i is the SA1 (origin) population, summed over all SA1s in the relevant RA. The population weighted average number of UCLs is similarly, $\sum_i Num\_UCLs_i \times Pop_i / \sum_i Pop_i$. The average UCL population size is $\sum_j P_j / N$ summed over all SA1s in the relevant RA where P_j is (as previously defined for the CI) the UCL population for destination j and N is the total number of SA1s in the RA.

Table 3.3 Maximum connectivity indexes for Remoteness Areas

Remoteness Area	CI education	CI health	CI employment	Number of UCLs	UCL population size
Inner regional	2,563	3,654	35,274	276	6,884,254
Outer regional	1,251	1,371	12,010	271	6,371,333
Remote	362	388	2,456	106	2,117,826
Very remote	235	285	1,423	50	217,970

Figure 3.8 Distributions of selected variables outside major cities by employment connectivity index

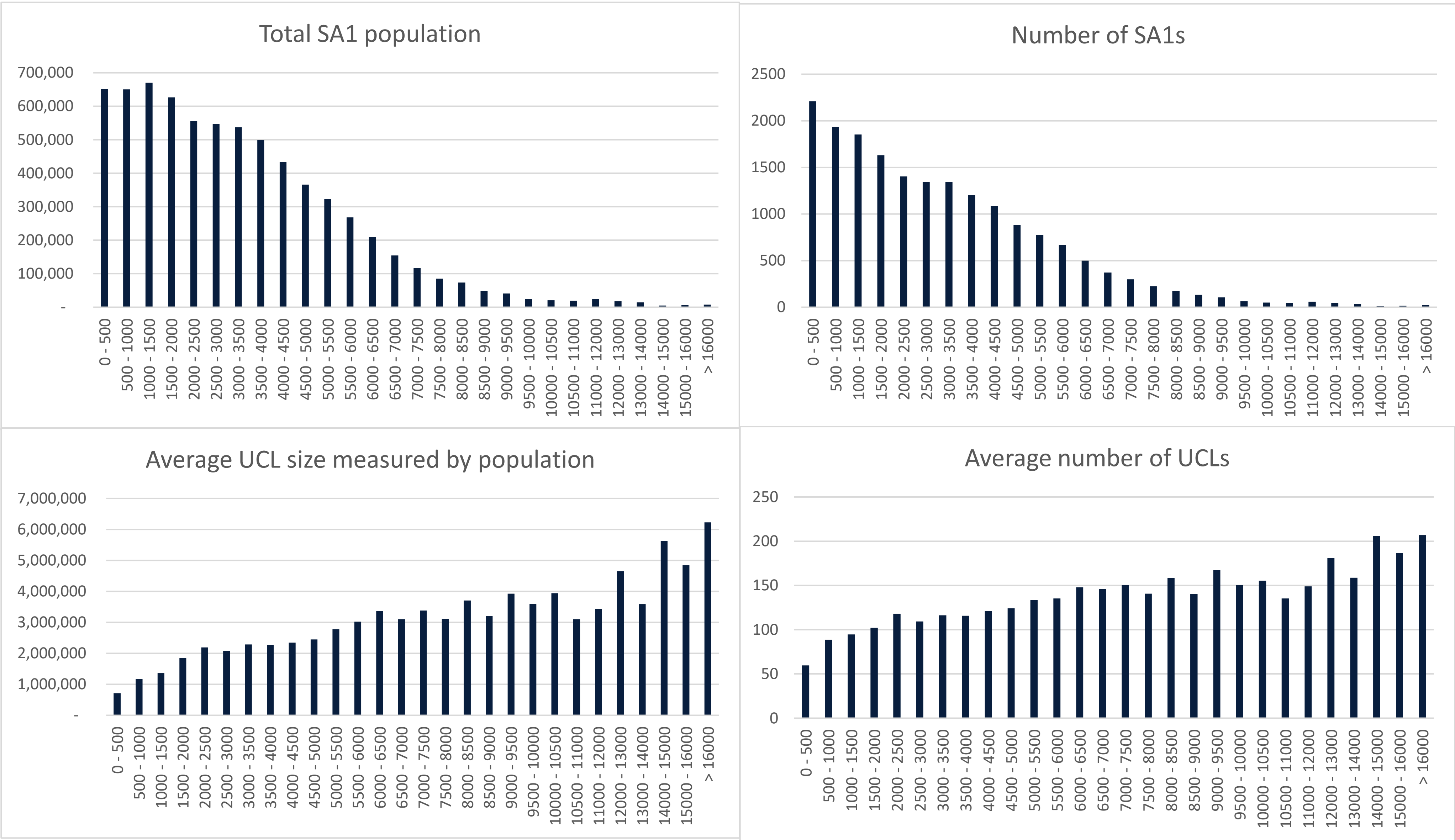
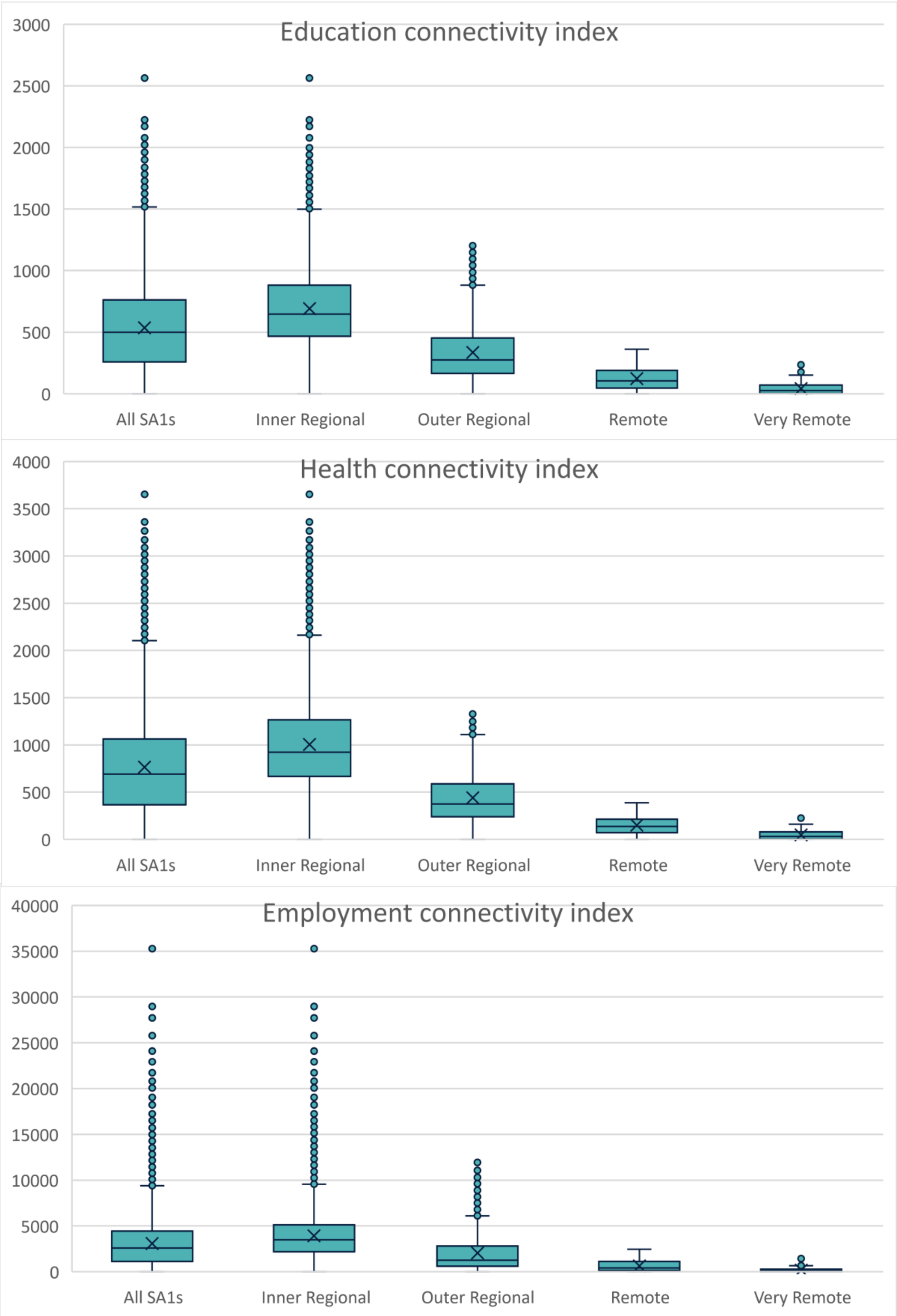
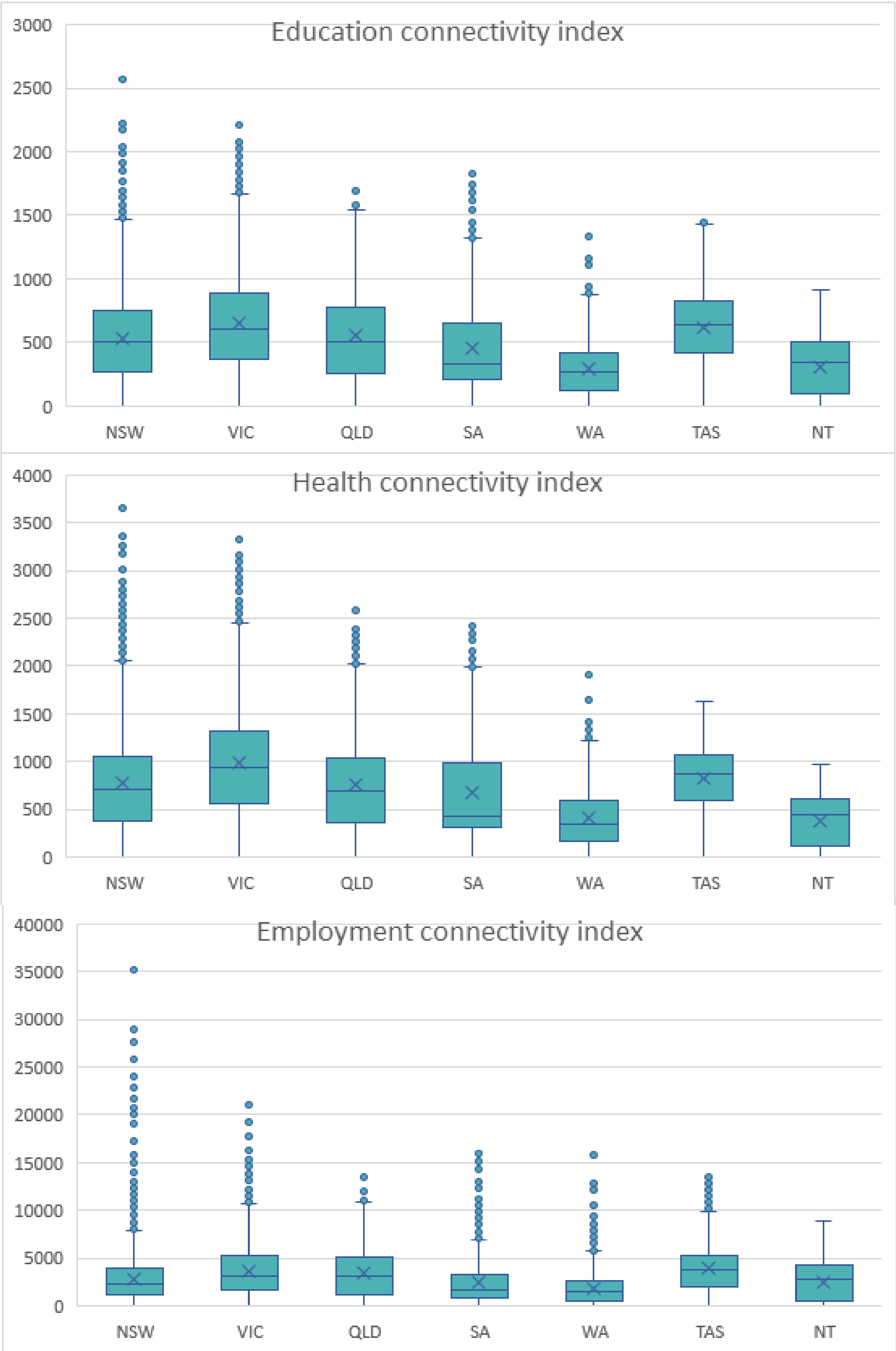


Figure 3.9 Whisker plots of connectivity indexes by Remoteness Area



Notes: These whisker plots show numbers of SA1s outside major cities, not population. The boxes show the range of the 25th and 75th percentiles of SA1s. Hence, 50% of SA1s lie within the box. X marks the average index value. The horizonal line in the middle of each box is the median or 50th percentile. In all cases the bottom of the range is zero. The whisker above each box is at 1.5 times the interquartile range (the difference between 75th and 25th percentiles. The points above the boxes are individual outliers.

Figure 3.10 Whisker plots of connectivity indexes by state and territory



Notes: These whisker plots show numbers of SA1s outside major cities, not population. The boxes show the range of the 25th and 75th percentiles of SA1s. Hence, 50% of SA1s lie within the box. X marks the average index value. The horizonal line in the middle of each box is the median or 50th percentile. In all cases the bottom of the range is zero. The whisker above each box is at 1.5 times the interquartile range (the difference between 75th and 25th percentiles. The points above the boxes individual outliers. ACT is not shown because there are only 8 SA1s in the ACT outside the Major Cities RA.

Figure 3.10 features whisker plots of the 3 CIs by state and territory. Northern Territory and Western Australia have the largest proportions of SA1s with low connectivity followed by South Australia.

Table 3.4 shows the data for percentiles of the population outside major cities. To illustrate, 90% of the 7 million population of the SA1s in the data live in SA1s with CI values below 1,022 for education, 1,494 for heath and 6,380 for employment. The most access disadvantaged 10% of the population have CI values of below 146 for education, 210 for health and 543 for employment.

Table 3.4 Example cumulative population percentiles

Population percentile	Connectivity index		
	Education	Health	Employment
99%	1,467	2,281	11,224
95%	1,172	1,711	7,737
90%	1,022	1,494	6,380
75%	784	1,090	4,602
50%	528	730	2,825
25%	293	407	1,324
10%	146	210	543
5%	81	119	268

The correlation coefficients between the education and health CI values is 0.98, but it is 0.94 between employment and education, and 0.90 between employment and health. The relationships are closer for the logs the CIs, which is a measure of utility from access. After removing CIs with values below one, the correlation coefficients between the logs of the CIs are 0.99 between education and health, 0.98 between employment and education and 0.96 between employment and health. The close relationships between the logs of the CIs are illustrated in the plots in Figure 3.11. Each point shown is an SA1.

A further step in analysing the CIs was to assess their relationships with 5 key demographic variables from the 2021 Census data. Table 3.5 presents correlation coefficients for the 18,494 SA1s in the data. The correlation coefficients indicate that, as remoteness reduces, age, average number of persons per bedroom and percent Indigenous falls, while income and the percent unemployed rise. For comparative purposes, Table 3.6 presents the averages for the SA1s for the ABS RAs. Note that as the CIs were not calculated for the Major Cities RA, the correlation coefficients apply only to outside major cities. The Major Cities RA averages are included in Table 3.6 for comparison only.

The relationships between remoteness and median age in SA1 in Tables 3.5 and 3.6 appear inconsistent. Median personal weekly income has a small positive correlation with the employment CI but median person weekly income is highest in the Remote RA. This may be due to people employed by the mining and agriculture industries. Both tables indicate that the proportion of Indigenous people is considerably higher in more remote areas.

Figure 3.11 Plots of logs of connectivity indexes for SA1s for the 3 types

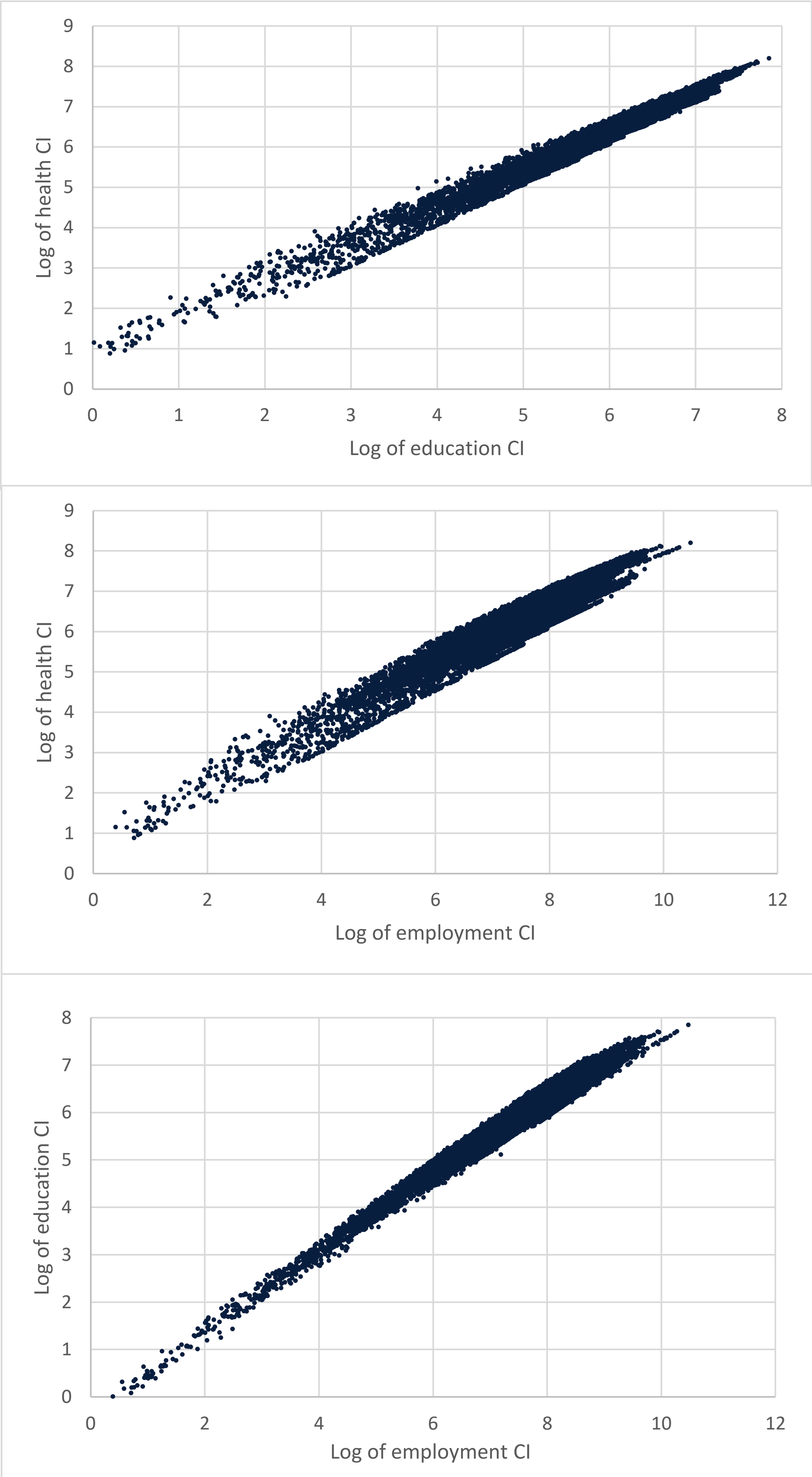


Table 3.5 Correlation coefficients between connectivity indexes and selected census variables for SA1s

	Median age	Median weekly personal income	Average number of persons per bedroom	Percent un-employed	Percent Indigenous
CI education	–0.07	0.02	–0.12	0.06	–0.23
CI health	–0.03	0.00	–0.12	0.03	–0.26
CI employment	–0.15	0.09	–0.06	0.08	–0.18

Note: Major cities are excluded because CIs were only estimated for SA1s outside major cities. Percent unemployed is expressed as a percentage of total population not working age population.

Sources: ABS 2021 Census of population and housing: General community profile datapack.

Table 3.6 Averages of selected census variables for Remoteness Areas

	Median age (years)	Median weekly personal income ($)	Average number of persons per bedroom	Percent un-employed	Percent Indigenous
Major cities	38.8	889	0.85	2.7%	1.8%
Inner regional	44.0	738	0.76	2.2%	4.5%
Outer regional	43.3	766	0.78	2.2%	7.3%
Remote	39.3	965	0.85	1.8%	15.3%
Very remote	34.9	842	1.08	2.9%	40.6%
Total	40.0	851	0.83	2.5%	3.2%

Note: These are population-weighted averages across SA1s. Percent unemployed is a percentage of total not working age population.

Sources: ABS RA_2021_AUST.xlsx for correspondences between SA1s and RAs. ABS 2021 Census of population and housing: General community profile datapack.

To examine the relationships between the employment CI and demographic variables in more detail, the bar charts in Figure 3.12 were constructed by dividing the range of index values into 25 intervals each with a similar population size of about 280,000 persons. The heights of the bars are population-weighted averages of the SA1s in each group.

While the overall relationships indicated by the correlation coefficients in Table 3.5 are confirmed, the charts show there is more to the story, particularly in relation to the most remote SA1s. All the panels in Figure 3.11 show an abrupt change for the most remote group (the leftmost bar in each panel). The explanation lies in the high percentage of Indigenous people in the most remote areas, and their being, on average, younger, have lower incomes, are more likely to be unemployed.

The proportion of Indigenous people in each SA1 appears to be a major factor explaining the demographic characteristics of SA1s outside major cities. For SA1s outside major cities, the correlation coefficients in the 2021 Census data between proportion Indigenous and median age is –0.33, median personal income, –0.21, average number of persons per bedroom, 0.51, and proportion unemployed, 0.30.

Figure 3.12 Distribution of demographic variables by employment connectivity index

3.5 Estimating induced trips from changes in connectivity index values

Where a road improvement reduces travel time between an SA1 and a UCL, the relationship between CI and numbers of trips can be used to estimate the number of induced trips for each of the 3 trip purposes. A road improvement will result in time savings for residents of one or more SA1s travelling to one or more UCLs. A separate induced trips calculation will be needed for each SA1 affected. For a single SA1, the road improvement may be on a road that is used to access multiple UCLs, so more than one term in the CI sum of terms could change.

The number of induced trips for a given trip purpose will be the factor from Table 3.1 above estimated by regression analysis, times the change in the CI, times the size of the relevant population, that is

$$Induced\ trips\ per\ day = \Delta CI \times factor \times relevant\ population$$

Table 3.7 summarises information needed to estimate induced trips from changes in CIs.

Table 3.7 Summary of inputs for estimating induced trips

Trip purpose	λ	μ	Factor	Relevant population
Early childhood education	–0.05	0.6	103.69×10^{-6}	ages 0 to 5
Primary and secondary education	–0.05	0.6	15.96×10^{-6}	ages 7 to 16
Tertiary education	–0.05	0.6	64.91×10^{-6}	ages 18 to 25
Health	–0.04	0.6	1.64×10^{-6}	all
Employment	–0.06	0.8	1.88×10^{-6}	working age (15 to 64)

From the CI formula, the change in CI from a travel time reduction for one or more UCL destinations is

$$\Delta CI_i = \sum_j e^{\lambda\, t_{ijPC}} P_j^{\mu} - \sum_j e^{\lambda\, t_{ijBC}} P_j^{\mu}$$

where the subscripts *BC* and *PC*, indicate travel time in the base case and project case respectively. Worked examples are provided in Appendix B.

3.6 Conclusion

Accessibility measurement plays 2 roles in the methods in this report for assessment of road investment in remote and regional areas. First, changes in accessibility are used to predict induced trips for the purpose of estimating social benefits, which contribute to economic efficiency, discussed in the next chapter. Second, accessibility is an indicator of transport inequality and is used to calculate equity weights for CBAs for projects in remote and regional areas, discussed in Chapter 7.

The CI employed in the report is the utility-based accessibility measure. It has a rigorous theoretical basis and slots into the utility model in Chapter 7 that underlies the proposed equity weighting system. The parameters in the models have been calibrated using estimated trip numbers. Parameters for CIs have been estimated for three trip purposes — education, health and employment. The logs of the three CIs for SA1s are highly correlated. Correlations between the CIs and a number of census variables at the SA1 level are very low. An exception is the negative correlation with the percentage of Indigenous persons in the population.

When the SA1s in the data are categorised by ABS's RAs outside major cities, there is overlap in the CIs. This can be explained by our CI being designed to take into account only relatively nearby destinations for which people make short, frequent trips, while ARIA+ considers access to much more distant destinations. Also, the removal of anomalies in setting RA boundaries would have contributed.

4. Social benefits

4.1 Introduction

This chapter and the next address inclusion in CBAs of remote and regional road projects of additional economic efficiency benefits over and above the benefits counted in conventional CBAs. All benefits in CBAs are 'social benefits' in the usual sense of the term in economics, because they accrue to members of society. In this report, we use the term 'social benefits' in a narrower sense to refer to quality-of-life benefits, specifically in relation to improvements in access to education, healthcare and employment.

There is a large body of literature, much of it from developing countries, that shows correlations between road access to remote and regional communities and a range of indicators of social wellbeing or quality of life — health, education, crime, domestic violence, substance abuse, suicide, unemployment and poverty (for example, Sieber & Allen 2016). The conventional method for calculating benefits from road improvements for induced trips, based on savings in generalised costs, might not capture the full social value of quality-of-life benefits. Godavarthy et al. (2014) provide an example of the type of social benefit considered here. Undertaking a CBA of 'rural and small-urban transit [public transport]' in the US, they calculated the benefits of non-emergency medical trips that would be missed in the absence of public transport as the cost difference between well-managed and poorly managed health care, plus improvements in quality of life, minus costs of the additional medical treatment required. They also considered benefits to society from additional work and education trips. (See Appendix A for further detail on Godavarthy et al. 2014.)

CBAs of non-urban road projects usually assume there is no induced travel at all because for longer-distance trips, a transport improvement over several kilometres of road length leads to only a small proportional reduction in generalised total trip costs. Benefits therefore accrue only for 'existing traffic' and are estimated from the fall in generalised costs. A methodology was developed in Chapter 3 for estimating numbers of induced trips for 5 trip purpose types from improvements to accessibility for SA1s in remote and regional areas. This chapter recommends dollar values for each of the 5 trip purposes to convert induced trip estimates into project social benefits. The worked examples in Appendix B illustrate how they can be combined with induced traffic estimates.

The unit benefit values developed are highly approximate. They are intended for application to all projects to which the benefits are relevant, regardless of their exact remote or regional location. CBA practitioners can use them at their desk-tops without further research, much like other standard parameter values published in CBA guidelines. The values could be refined through detailed research efforts.

For education and health benefits, the estimates are averages over a cohort of individuals and numbers of trips per annum. There is an assumption that the marginal social benefit from a trip equals the average social benefit.

KPMG (2025) undertook a literature review and made preliminary unit benefit estimates for each of the 3 benefit types. New estimates were made for this chapter drawing on KPMG's methodology. Their literature reviews are the basis of Appendix A, titled 'Supporting literature on social benefits'.

4.2 The concept of social benefits

The social benefits referred to here are genuine economic efficiency benefits but are distinct from WEBs. WEBs arise from imperfections in labour and product markets. In contrast, the 'social benefits' under consideration here arise from:

- Individuals not recognising the full value to themselves and their families of increased use of road transport to access education, health and other services
- Quality-of-life benefits to other community members (positive externalities) from better health, education and employment outcomes for individuals in the community

- Savings in costs to governments in provision of services in areas such as health, education, law and order, and remedial social programs.

The first source of benefits is similar to the difference between perceived and social generalised costs for transport. Where car drivers perceive time but not vehicle operating costs, there is a *negative* 'resource correction' to be made for the unperceived costs of trips induced by a road improvement, that drivers do not take into account when making travel decisions (ATAP 2022a T2, p. 41; ATAP 2022b M2, Section 7.3). Where drivers fail to perceive additional benefits to themselves from induced trips, causing social costs to be less than perceived costs, there is a *positive* resource correction to be made to a consumers' surplus benefit estimated from the change in perceived costs (ATAP 2022a T2, p. 38).

The second source of benefits, positive externalities from additional trips leading to better social outcomes, is another case of drivers not perceiving the full social value of travel. The general amenity level for a community will be higher when its members are healthier, better educated and employed.

The third source of benefits is based on the assumption that governments will pay for services to achieve outcomes at certain levels in the base case, and that in the project case, the government achieve the same outcome levels at a lower cost. For example, more visits to general practitioners can reveal health problems sooner, avoiding high costs of treatment in hospitals later. A community with less crime will cost the government less for policing, legal and correctional services.

Reduction of unemployment in remote and regional communities has a range of positive outcomes, one of which is additional tax revenue for governments. The additional tax paid is, in fact, a WEB, and as such, belongs in Chapter 5. However, it has been included in this chapter because it is a monetary benefit associated with induced trips and it is combined with a value for the positive external effects.

Figure 4.1 presents the conventional model of the consumers' surplus benefit for an upgrading project on an uncongested road with the addition of a marginal social benefit curve. The demand curve graphs the number of trips along a road as a function of the generalised cost. The height of the demand curve at a given quantity of trips is the WTP by the road user of that particular unit of trips. If an improvement to the road lowers the generalised cost, the benefit to existing traffic is the rectangular area *a*. The perceived benefit to induced or generated traffic is the triangular area *b*. The sum of areas *a* and *b* is the consumers' surplus change discussed in Section 2.2.2.

The rule-of-half, which is applied to induced traffic, accounts for the private gains that beneficiaries (the trip makers) perceive. It assumes a uniform distribution of WTP values starting from the user not quite willing to pay the base-case cost and going down to the user only just willing to pay to project-case cost. The rule-of-half will underestimate benefits in cases where there are unperceived benefits or positive externalities.

In Figure 4.1, the unperceived benefits to the trip makers, benefits to other members of society and savings to governments, have been added to private WTP (the demand curve) to obtain a 'marginal social benefit curve'. It shows the combined WTP of *all* members of society for each trip, including the trip makers if they were able to fully perceive the benefits to themselves. The additional unperceived benefits from induced travel are given by area *c* between the marginal benefit curve and the demand curve.

The social benefits in area *c* exist only for induced trips.[13] The social benefits associated with existing trips will already accrue in the base case.

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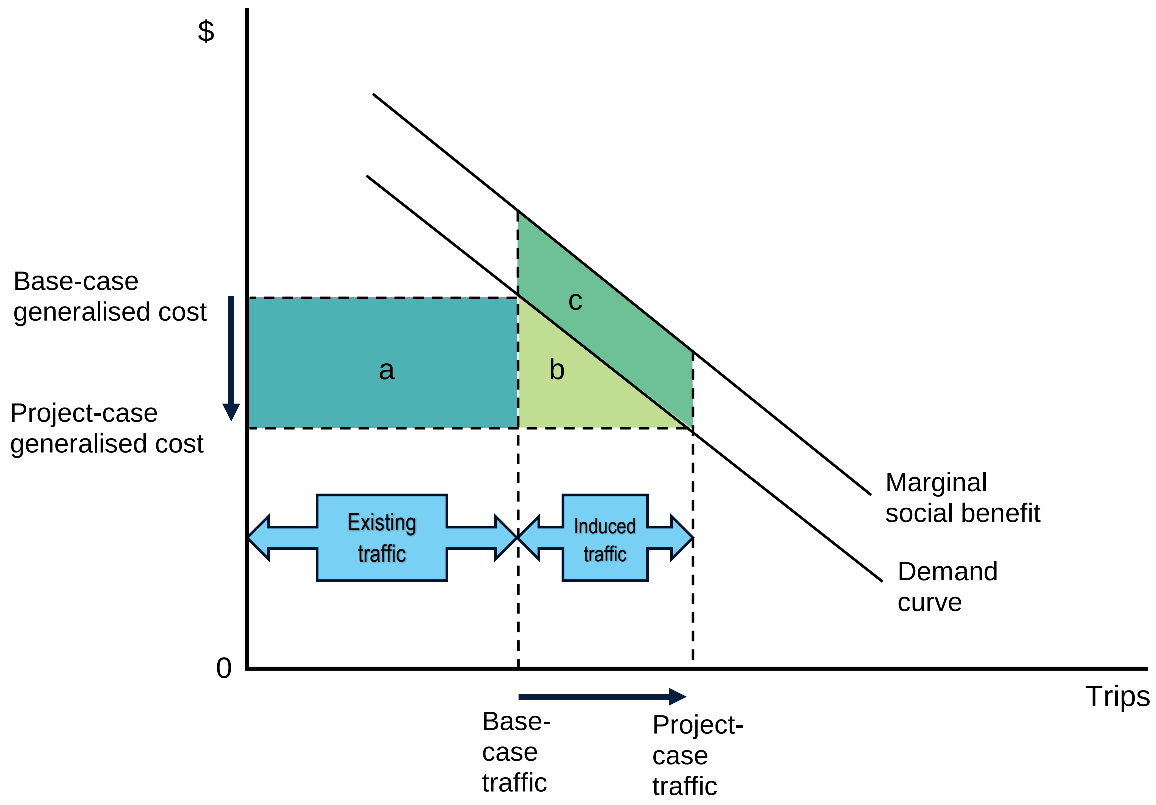
[13] The ATAP Guidelines glossary defines generated traffic as altogether new (freight, passenger or vehicle) demand resulting from an initiative — that is, it would not exist but for the initiative (ATAP 2016a A2, p. 9). ATAP defines induced traffic as the sum of generated and diverted traffic (diverted from other routes, transport modes or times of travel). As diverted traffic is not a consideration for social benefits, the present report uses the terms 'generated' and 'induced' interchangeably.

Figure 4.1 Social benefits from a road improvement



The social benefit estimates include an allowance for positive externalities from increased education and employment trips for the effect of better education and being employed on the health of the individuals making the trips, and the effects on their communities of reduced crime and increased social cohesion. These benefits are not exhaustive. Where there may be further benefits that CBA is unable to monetise, they can be recognised in CBA reports as 'non-monetised' benefits with explanations as to why they could be significant in particular instances. This point is addressed in Chapter 8.

Provided there no market imperfections, secondary benefits, such as increased tourism, land values and industry development, are already valued by the conventional consumers' surplus measure. Adding monetary amounts for these to a CBA will result in double counting.

For education, health and employment benefits, dollar amounts per round trip have been estimated for use by practitioners in CBAs. In the cases of education and health, the benefit values include the perceived benefits to the trip makers concerned. The perceived benefit would be part of area *b* of Figure 4.1 for those particular trips (in addition to perceived benefits in area *b* for induced trips for other purposes). The definition of 'social benefits' in this report for education and health therefore covers both perceived and unperceived benefits to induced traffic. Hence, it is the sum of areas *b* and *c* in Figure 4.1. Having estimated the social benefit, it would be double counting to add on the consumers' surplus gain for these trips calculated using the rule-of-half — that is, half the reduction in generalised costs times the number of trips. *If social benefits are estimated for induced education and health trips using the unit monetary values below, the rule-of-half benefit cannot be counted.*

For employment trips, the social benefit is the sum of positive externalities and additional tax revenues for governments, neither of which accrue to the individuals making the trips. As the employment social benefits are not perceived by the trip makers, they are exclusively in area *c* of Figure 4.1 and are additional to the rule-of-half benefits accruing to the trip makers. *Rule-of-half benefits for employment trips should be added to the tax revenue and externality components to obtain the full social benefit amount.*

With a similar concept of social benefits to the one in this report, Baker et al. (2017) estimated social benefits from improved access to medical care, mental health care and employment for 5 case-study CBAs of rural road upgrades in the Moree Plains and Gwydir Shires of Western New South Wales. They concluded that social benefits are small in relation to the other benefits. Their methods for estimating social benefits, however, were different from ours, relying on assumed elasticities for forecasting induced trips, and additional working time gained valued at the wage rate for monetising benefits.

4.3 Education benefits

Children and young people in remote areas face higher barriers than in cities. In the 2021 Census, 53% of children aged 3, 4 and 5 attended preschool for the whole country, but only 25% in the Very Remote ABS RA (ABS Tablebuilder). School students in remote and regional schools perform at lower levels than in metropolitan schools (Thomson et al. 2019, pp. xxi-xxii). Higher travel times may negatively impact students' lives by increasing fatigue, reducing attentiveness in class, or impacting family life and children's out-of-school time (OECD 2017, p. 5).

Percentages of persons aged 15 to 74 as at 2024 with bachelor degrees and above were 41% for the Major Cities RA and 23% for the other RAs combined (ABS, 2024. Education and Work, Australia, Table 34)[14]. Contributing factors include:

- limited local higher education study options
- the financial, emotional, and social challenges associated with relocating to study
- differences in student experiences and aspirations, and
- other forms of disadvantage that correspond with location, such as being from lower socioeconomic status households, being Indigenous, and/or studying part time (Ferguson 2022).

For education benefits, the methodology was to estimate the present value of lifetime benefits from a specified additional amount of education, then divide it by the number trips necessary to obtain that specified amount, for example one year of education.

4.3.1 **Early childhood education**

Early childhood education (ECE) refers to care and education services provided to children up to 5 years old and before they begin attending primary school. These services can be in formal settings such as a childcare centre or family day care or informal settings such as in-home care. In Australia, attendance at ECE is not mandatory, however, subsidies are available to encourage the use of ECE.

There is extensive evidence supporting the existence of substantial benefits from ECE. Appendix A.1 reviews a number of overseas and Australian studies. Each of these studies contains a literature review pointing to still more evidence.

Three key benefits arise from:

- Academic: children who attend ECE tend to achieve higher academic results than their peers.
- Social skills: children attending ECE generally have better self-regulation and co-play than their peers.
- Attitudes towards education: children attending ECE generally go on to be more engaged with primary and secondary education and are more likely to pursue post-secondary qualifications.

There are further benefits to primary carers who have more time available for employment, education, or leisure. These benefits have been well documented in Australia due to the recent focus on the cost of ECE and its relationship to women's workforce participation.

Finally, there are wider economic and community benefits from primary carer productivity and well-educated young Australians. Governments gain from higher tax receipts and lower welfare payments, offsetting the cost of childcare subsidies.

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[14] https://www.abs.gov.au/statistics/people/education/education-and-work-australia/latest-release#data-downloads

We relied on the CBA of ECE in Australia in PwC (2019) to obtain a benefit per additional trip for ECE purposes to use in CBAs of road improvements in remote and regional areas. The PwC (2019) CBA was confined to the ECE provided in a single year, 2017, to children in the year before commencing school, often referred to as pre-school or kindergarten. The costs identified were spending by governments and by households. The largest benefit categories were higher parental earnings, higher earnings by children over their lives and the resultant higher taxes accruing to governments. Other benefits included productivity gains to employers and reduced health-related and crime-related expenditures. The full table of costs and benefits is reproduced in Appendix A. Using a 3% discount rate, PwC (2019) estimated the present value of benefits at $4,737 million and costs at $2,366 million, giving a net present value of $2,401 million in 2017 prices and a BCR of 2.0. This ratio is conservative compared with the BCRs found in the international studies reviewed, ranging up to 7.3.

The 3% discount rate is below that used for road improvements, but PwC maintained it was consistent with other studies of long-term benefits of social programs. A total of 295,826 children were enrolled in a year-before-school pre-school program in 2017, and were therefore within the scope of the PwC (2019) CBA (Productivity Commission, RoGS 2019, Table 3A.18). Using PwC's 3% discount rate, the average net benefit per child for the one year of participation in ECE as a present value is

$$\frac{\$2{,}401\ million\ net\ benefit}{295{,}826\ \text{children}} = \$8{,}116\ per\ child$$

PwC (2019, p. 20) assumed that children attended ECE for an average of 15 hours per week. Assuming this is spread over 3 days a week and occurs for 48 weeks per year, the benefit per round trip is $56.36. Inflating this to 2024 dollars, the benefit value becomes $71 after rounding.

PwC did not provide discounted present values of net benefits at other discount rates, only BCRs of 1.7 at a 4% discount rate and 1.1 at a 7% discount rate. An interpolated BCR at 5% is 1.5. Assuming all costs are incurred during year 1 and estimating benefits from the BCRs, the benefit value of $71 per trip at the 3% discount rate reduces to $48, $35 and $5 at the 4%, 5% and 7% discount rates respectively.

4.3.2 **Primary, secondary and tertiary education**

Increases in educational attainment lead to higher lifetime incomes for the individuals concerned as well as a range of other benefits. People with higher levels of formal education are more likely to be employed, lead healthier lifestyles (not smoke, exercise more, consume less alcohol), participate in voluntary work, give donations, be more environmentally conscious, and better engage with institutions. Benefits to society beyond the individual include more taxes collected by governments, reduced reliance on the welfare and aged pension systems, reduced crime, lower health costs, better informed political debate and a stronger civil society.

Primary education delivers some of the most critical skills to children — how to read and write, basic mathematics, and continues to develop their social skills. Secondary education builds on these skills to include more advanced mathematics, reading comprehension and critical thinking, as well as exposing young adults to a broader range of subjects such as languages, sciences, and the arts. Then, tertiary education ranging from Certificate III/IV to PhD, imbues students with specific skills often linked to specific industries or occupations, in particular, for trades and occupations that require certain certifications.

Numerous studies have investigated the relationship between earnings and educational attainment. Appendix A.2 surveys a selection of these studies, concentrating on Australian examples. The typical methodology is to estimate an econometric relationship between the log of earnings (hourly or annual) and years of work experience, variables for personal characteristics, and either years of education or dummy variables for the level of educational attainment. The result can be presented either as the addition to hourly or annual earnings from an additional year or level of attainment (dollar amount or percentage increase), or the addition to lifetime earnings, taking into account earnings forgone during years spent in education. Typically, studies of this type find that an additional year of education increases annual earnings by around 10%.

Econometric studies face complexities from factors that affect earnings not observable by the analyst such as differences in individual ability, financial constraints, family background and preferences leading to an endogeneity problem (Aakvik et al. 2010, p. 2). The 'signalling theory' or 'screening hypothesis' posits that the positive relationship between education and earnings is due in part to the way educational qualifications send a signal to potential employers that a job applicant will be a good worker. The literature is divided about the possible significance of signalling (see Appendix A).

The estimates for benefits from additional trips for primary, secondary and education purposes were derived from the most recent Australian research, Leigh (2024). Leigh undertook ordinary least squares regressions of data from the Household, Income and Labour Dynamics in Australia (HILDA) survey. After adjusting downward for a 10% ability bias (the percentage return multiplied by 0.9), Leigh found that annual earnings increased by 7% for completing Grade 11, 27% for Grade 12, 14% for each year of bachelor's degree and 14% for each year of a masters or doctoral degree. Full details are provided in Appendix A, Table A.2.

The methodology to obtain the benefit per trip was as follows.

- Obtain from ABS 2021 Census data, personal income and proportions of highest education level attained for persons in each year age cohort from 15 to 64. For example, average annual personal income for persons aged 40 was $81,270, and of these, 13% had Grade 12 as their highest educational attainment and 24% had bachelor degrees.
- Express Leigh's results for each education level as a multiple of earnings for a person who had completed only up to Grade 9. For example, someone who had completed Grade 12 would earn 1.44 times and a bachelor degree 2.03 times as much as someone who left school after Grade 9.
- Using the earnings multiples and proportions of education attainments, estimate the annual income for a person with Grade 9 education for year age cohort from 15 to 64. For persons of age 40, implied earnings for someone who had only completed Grade 9 would be $48,824. The purpose of this step was to obtain a profile of life-time earnings for people with the same educational level.
- From the implied Grade 9 earnings and multiples for each education level, estimate earnings for each education level for ages 15 to 64. This generated a profile of lifetime earnings for each educational level.
- Replace earnings in the early years with zeros for time spent in education. For example, for Grade 12, zero earnings for ages 15 to 17, and zeros up to age 20 for a bachelor degree.
- Take the discounted present value of earnings from ages 15 to 64 for each education level. For example, the present value for Grade 12 is $1.27 million at a 3% discount rate and $0.81 million at a 5% discount rate.
- Estimate the increment in the present value of earnings for each additional year of education. Grade 11 lifetime earnings is $42,000 above Grade 10 earnings and Grade 12 adds a further $141,000 at the 5% discount rate. Allowance was made for qualifications that require multiple years. A bachelor degree adds $260,000 to lifetime earnings over Grade 12 at a 5% discount rate, but $87,000 for each of the required 3 years.
- Take the weighted average earnings increment using proportions of students currently in each grade or studying for each qualification. This step is needed because we require a single average benefit value for an additional year of education, one for primary and secondary and one for tertiary, averaged over all the years at school or a tertiary institution. Primary and secondary school education before year 10 is mandatory. The annual increment for Grade 10 over Grade 9 was assumed to apply for each year down to Grade 1. Estimates and further calculations are shown in Table 4.1 at the 3%, 4%, 5% and 7% discount rates.
- Add a benefit for positive non-pecuniary externalities from education from improved outcomes to governments and broader society in relation to health, crime and social cohesion.[15] This was assumed to be 30% of gross private earnings based on McMahon (2004, p 244) and Chapman & Lounkaew (2015). This percentage is almost the same as that used in PwC (2019) for the assumed savings to governments

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15 Non-pecuniary externalities occur when the activity of one person directly affects the utility of another without any monetary transaction. Pecuniary externalities are passed on via the price mechanism.

from reduced health and crime-related expenditure from an additional year of ECE. PwC added 31% to all the other benefits.

- Deduct the cost of providing a year of education. For primary and secondary schools, ACARA (2022, p. 140) reported total recurrent expenditure per student for all schools together in 2021-22 as $22,511. Universities Australia (2022, p. 16) reported a government contribution of $11,390 and student contribution of $8,380.
- Divide the annual benefit by 180 trips per year and inflate from 2021 to 2024 prices using the full-time adult ordinary earnings index.

Table 4.1 Estimation of benefit per trip for education at various discount rates ($)

	3%	4%	5%	7%
Primary and secondary education				
Present value of life time earnings per student for an additional year of education, averaged over all years	95,860	75,877	60,985	41,085
Externalities	28,758	22,763	18,296	12,325
Operating cost of schools per student per year	–22,511	–22,511	–22,511	–22,511
Net benefit	102,108	76,129	56,770	30,899
Benefit per trip assuming 180 trips per year	567	423	315	172
Benefit per trip in 2024 prices	**628**	**468**	**349**	**190**
Tertiary education				
Present value of life time earnings per student for an additional year of education, averaged over all years	107,292	79,846	59,788	33,890
Externalities	32,188	23,954	17,936	10,167
Government contribution to universities per student per year	–11,390	–11,390	–11,390	–11,390
Student contribution to universities per student per year	–8,380	–8,380	–8,380	–8,380
Net benefit	119,710	84,030	57,954	24,287
Benefit per trip assuming 180 trips per year	665	467	322	135
Benefit per trip in 2024 prices	**736**	**517**	**356**	**149**

An issue with the concept of a benefit for an additional year of primary school and early high school education is that attendance to school leaving age is mandatory. This means that all Australian children will receive a minimum of 10 years of formal education, though the census does provide numbers of persons who only completed years 8 and 9, or who did not go to school.[16] Ideally, we would draw on estimates in the literature on costs of students missing additional days of schooling up to year 10, for example, due to truancy or illness. However, such estimates do not appear to have been made. The weighted average value of an additional year of education is assumed to cover both additional days of attendance in years 1 to 10, and optional additional whole years of education in years 11 and 12 or equivalent.

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16 These are in larger numbers for older age cohorts, and people born overseas may be disproportionately represented.

4.4 Health benefits

Improved access to healthcare facilities can lead to earlier detection and better management of health issues leading to better outcomes for individuals and savings in healthcare costs for governments. Regular visits to primary health care should allow more orderly and proactive delivery of preventative care and care management, which can help avoid emergency department visits and hospitalisations (Rose et al. 2019, p. 82). Appendix A.3 reviews supportive literature. Mseke et al. (2024) mentioned road quality as a consideration in healthcare access.

Rural and remote communities face significant challenges in accessing healthcare services compounded by geographic isolation, limited healthcare infrastructure and workforce shortages (Baazeem et al. 2024, p. 3). The AIHW reported there are 21 medical specialists per 100,000 population in very remote communities compared with 152 in metropolitan areas.[17] According to the National Rural Health Alliance, the number of GPs providing care per capita drops with increasing remoteness. For the year 2021-22, there were 125 GPs per 100,000 people in metropolitan areas compared to 85 in small rural towns and 67 in very remote communities.[18] The additional time and transportation costs to access health care services means people in remote and very remote areas may delay access to preventive and primary health care and rely on hospital care to have their needs met (AIHW 2024). The situation is particularly acute for Indigenous communities, who also face cultural and linguistic barriers to accessing health care (Baazeem et al. 2024, p. 3). Bishop et al. (2023) reported that 45,000 people in remote and very remote Australia have no access to any type of primary healthcare service within a 60-minute drive time of their place of residence. GP visits per person are lower in remote and very remote areas as shown in Table 4.2, while hospitalisations per head of population are higher.[19] There are many other statistics that could be presented to illustrate the extent of the health disadvantages for people in remote and very remote areas (see for example, Bishop et al. 2023).

Mental health is also an issue in remote and regional areas. In 2022-23, the recorded rate of intentional self-harm hospitalisations per 100,000 population was 169 in very remote areas compared with 89 in major cities. The highest rate was for the 20-24 age group in very remote areas (435 hospitalisations per 100,000 population), followed by the 15–19 age group from Remote areas (417 per 100,000 population).[20] A similar pattern occurs for deaths by suicide as age-standardised suicide rates tend to increase with remoteness of place of residence. In 2022-23, numbers of deaths by suicide per 100,000 population in the 5 Remoteness Area categories respectively ranging from Major Cities to Very Remote were 10.0, 15.9, 17.6, 20.3 and 21.0 (AIHW 2024, Deaths due to suicide: National mortality database). Caldwell et al. (2004) reported that higher suicide rates were evident for men, particularly young men in rural (40.4 per 100,000) and remote (51.7 per 100,000) populations compared with metropolitan (31.8 per 100,000) populations. Although the proportion of young men reporting mental health disorders did not differ significantly between rural (23.5%) and remote (18.8%) areas compared with metropolitan (25.6%) areas, young men with a mental health disorder from non-metropolitan areas were significantly less likely than those from metropolitan areas to seek professional help for a mental health disorder (11.4%).

The AIHW publishes data on numbers of visits to attend Medicare-subsidised services including GPs, and ABS publishes mortality statistics at the SA3 level. Table 4.2 shows population-weighted averages, categorising the SA3 areas by RA.[21]

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17 https://www.aihw.gov.au/reports/rural-remote-australians/rural-and-remote-health

18 https://hwd.health.gov.au/resources/data/dataset-gp-financial-years-201516-to-202122.xlsx

19 AIHW reported hospital separations per 1000 population in 2022-23 by Remoteness Areas as 407 Major Cities, 411 Inner Regional, 434 Outer Regional, 536 Remote and 821 Very Remote. A separation is defined as an episode of care for an admitted patient. https://www.aihw.gov.au/hospitals/topics/admitted-patient-care

20 https://www.aihw.gov.au/suicide-self-harm-monitoring/overview/summary

21 The categorisation of SA3s into Remoteness Areas is from AIHW. ABS's Remoteness Areas classes are built up from ARIA+ scores for SA1s. The boundary between Remoteness Areas can run through SA2s and above.

Table 4.2 Primary health trips and median age of death by Remoteness Area

Remoteness Area	GP visits per person per year	Other health-related visits per person per year	Ratio of other visits to GP visits	Median age of death (years)
Major cities	6.5	3.3	0.50	81.7
Inner regional	6.4	3.3	0.51	81.2
Outer regional	5.7	2.8	0.50	79.1
Remote/ Very remote	3.9	1.9	0.49	69.8
All Australia	6.4	3.2	0.50	81.1

Notes: Values are population weighted averages over all SA3s. GP and other health-related visits are for the year 2022-23. Other health related visits includes visits to specialists, diagnostic imaging, visits to nurses and aboriginal health workers, physiotherapy, and psychologists. Median age of death was averaged over the 5 years 2018 to 2022.

Sources: AIHW https://www.aihw.gov.au/reports/primary-health-care/medicare-subsidised-gp-allied-health-specialist/contents/about; ABS https://www.abs.gov.au/statistics/people/population/deaths-australia/latest-release#data-downloads

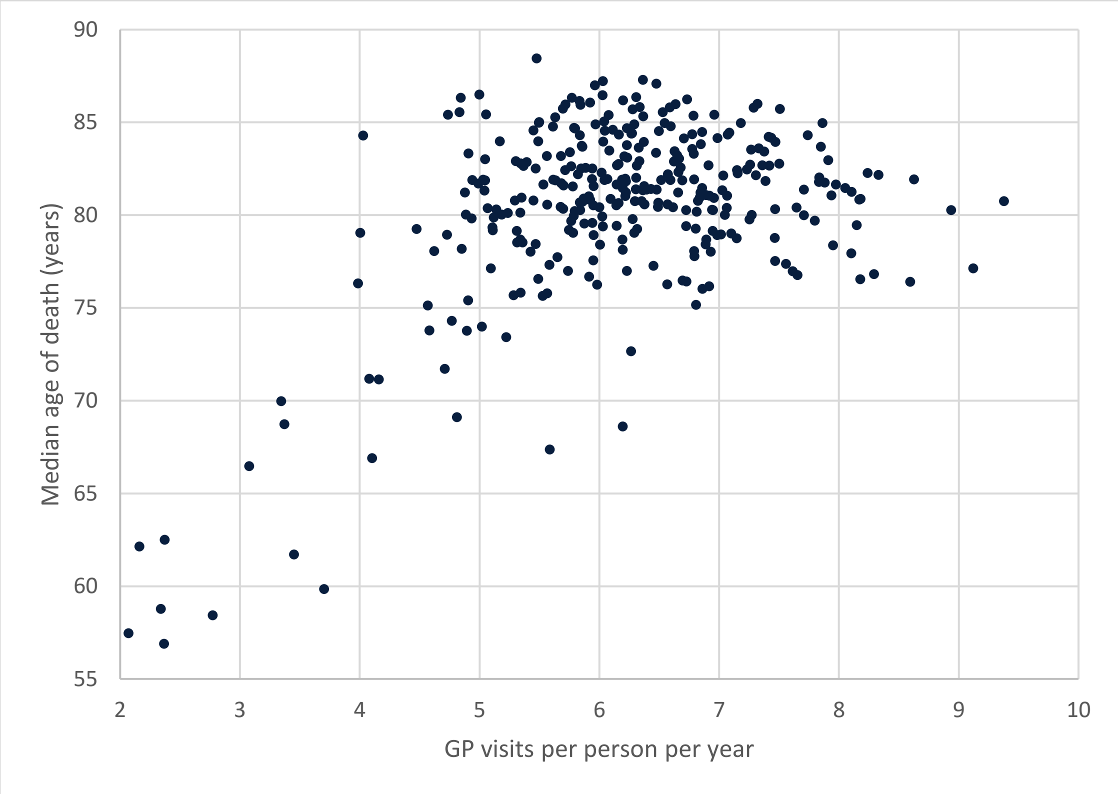
The methodology applied here to estimate the benefit from additional trips to primary health care is similar to that applied in Jollow and Kulkarni (2021). They used AIHW data to estimate the reduction in mortality rate for every unit increase in health services per person by remoteness. The reduction in mortality rate for the population benefitting from a transport improvement was monetised using a value of statistical life. Our method uses median age of death instead of mortality rate, and adjusts for other factors affecting longevity besides primary health care visits.

Figure 4.2 shows a plot of median age of death against GP visits per person per annum for 330 SA3s. There is a clear positive relationship up to a level of around 6 visits a year. However, it could not be claimed that primary health care visits are the sole determinant of life expectancy. Lifestyle factors also contribute. Table 4.2 shows AIHW data on the prevalence of health risk factors by RA. The majority of the factors increase with remoteness, in particular, smoking and alcohol consumption.

Variables that might be related to longevity were obtained at the SA3 level from the 2021 Census — income (personal, family and household), average household size, average number of persons per bedroom, proportion of the population female, proportion Indigenous, proportion unemployed, proportion having completed year 12 education and proportion with a bachelor degree or higher. Data on the lifestyle factors in Table 4.3 were not available at the SA3 level. However, their prevalence in each SA3 would be correlated with other variables in the regression analysis.

For estimating the unit benefit of an additional health trip, GP visits were used as the unit of account because this is the parameter used for trips as a function of the CI in Chapter 3. Table 4.2 shows that the ratio of other primary health care visits to GP visits is consistently around 50%.

Figure 4.2 Median age of death against annual GP visits per person by SA3s.



Sources: AIHW, https://www.aihw.gov.au/reports/primary-health-care/medicare-subsidised-gp-allied-health-specialist/contents/about; https://www.aihw.gov.au/reports-data/health-conditions-disability-deaths/life-expectancy-deaths/data AIHW-PHE-229-MORT_SA3_2018_2022.xlsx

Table 4.3 Health risk factors by Remoteness Area

Percent of population

	Major cities	Inner regional	Outer regional and remote
Current daily smoker	9.3	14.5	17.5
Exceeded lifetime alcohol risk guideline	26.1	30.6	32.7
High blood pressure	21.6	22	21.5
Inadequate fruit intake	56.1	56.9	59.9
Inadequate vegetable consumption	94.2	92.8	92.6
Insufficient physical activity	40.1	41.2	44.8
Overweight or obese	64.4	68.1	69.6

Source: AIHW (2024) based on self-reported data from the ABS's National Health Survey (NHS) and adjusted for age.

The methodology applied to obtain a dollar value for an additional primary healthcare visit was to estimate a relationship between median age of death and number of GP visits per annum, then monetise this by applying the standard value for Australia of a statistical life year. Developing a detailed statistical model to explain lifespans or the benefit from an additional GP visit is a major research task that is well beyond the scope of the present project. A simple model was developed using readily-available data.

As the positive relationship between GP visits and median age of death does not appear to continue above 6.0 visits per year in Figure 4.2 and the benefit parameter will be used only for areas in the lower part of the range shown, the data was truncated to exclude all SA3s with annual GP visits of above 6.5. This avoided the need for a more complicated functional form in the model and improved the model fit for the lower half of the range, but reduced the number of observations from 330 to 207.[22] A number of statistical models were tested using data from the 2021 Census.The final model selected for median death age (MDA) was

$$log(MDA) = \beta_0 + \beta_1 gpv + \beta_2 gpv^2 + \beta_3 log(apb) + \beta_4 log(pf) + \beta_5 log(pi)$$

which simplifies to

$$MDA = e^{\beta_0 + \beta_1 gpv + \beta_2 gpv^2} apb^{\beta_3}\, pf^{\beta_4}\, pi^{\beta_5}$$

The regression results with variable definitions are summarised in Table 4.4

Table 4.4 Regression results for log of median death age

Variable	Coefficient	Standard error	t-statistic
Intercept term	1.3630	0.0181	75.1768
GP visits per annum (gpv)	0.0449	0.0051	8.8300
GP visits per annum squared	–0.0039	0.0005	–7.6750
Log of average persons per bedroom (apb)	–0.0258	0.0056	–4.5752
Log of proportion female (pf)	0.0592	0.0138	4.2771
Log of proportion Indigenous (pi)	–0.0064	0.0006	–10.3281
r-squared = 0.800, number of observations = 207			

All the coefficients are highly statistically significant and have the expected sign.

In developing the model, variables tested and excluded on the grounds of lack of statistical significance or a coefficient with the wrong sign, were income (personal, household and family) and the proportions of the population unemployed, having completed Grade 12 and having a bachelors' degree. The variable 'average number of persons per bedroom' is an indicator of living standard and is likely to be correlated with some of the lifestyle factors listed in Table 4.3.

The partial derivative of MDA with respect to GP visits per annum is an estimate of the increase in MDA in an SA3 if the number of annual GP visits per person increased by one. It should be noted that each GP visit comes with an additional 0.5 of a visit to other health care providers, as illustrated in Table 4.2.

An additional visit per annum means a person makes one additional visit in every year of their life. The total number of visits over a lifetime is *Lgpv = gpv × MDA*. The benefit parameter per round trip to be used in CBAs has to be for one additional trip only, not a lifetime of additional trips. The increase in years lived as a result of a single additional GP visit is

$$\frac{\partial MDA}{\partial Lgpv} = \frac{\frac{\partial MDA}{\partial gpv}}{\frac{\partial Lgpv}{\partial gpv}} = \frac{\frac{\partial MDA}{\partial gpv}}{\frac{\partial (gpv \times MDA)}{\partial gpv}}$$

The derivative $\frac{\partial Lgpv}{\partial gpv}$ combines both the increase in GP visits of one for each year lived of the existing lifespan, and the GP visits over the additional years lived.

From the model and the coefficient estimates in Table 4.4

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22 Excluding observations with annual GP visits above 6.0 instead of 6.5, made little difference to the results. There were 137 observations, an r-squared of 0.826, and coefficients of β_1 = 0.0431 and β_2 = –0.0038.

$$\frac{\partial MDA}{\partial Lgpv} = \frac{\beta_1 + 2\,\beta_2\,gpv}{1 + \beta_1\,gpv + 2\,\beta_2\,gpv^2} = \frac{0.0449 - 2 \times 0.0039 \times gpv}{1 + 0.0449 \times gpv - 2 \times 0.0039 \times gpv^2}$$

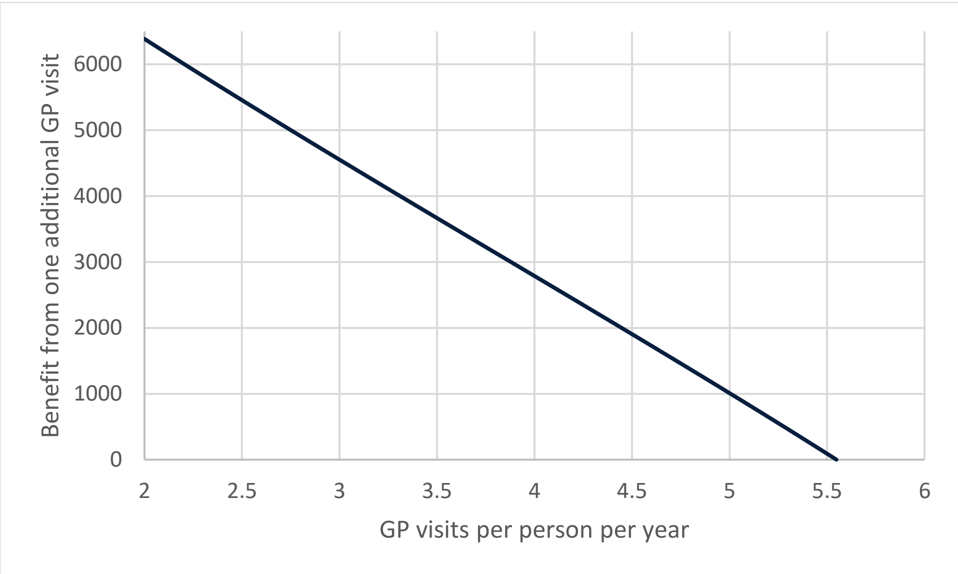
The variables other than GP visits per annum cancel out.

The model gives values of $\frac{\partial MDA}{\partial Lgpv}$ of 0.028 years for *gpv* = 2.0 declining to zero for *gpv* = 5.76, after which additional GP visits do not add to lifespan. This is consistent with Figure 4.2 where the positive relationship ceases to hold beyond around 6 visits per year.

To monetise the lifespan increase, we multiply by the value of a life year recommended by the Office of Impact Assessment (2024) of $245,000.

The cost of an additional GP visit needs to be deducted. From AIHW data, in 2022-23, $83.3 billion was spent on primary health care (including pharmaceuticals and other medications) to provide 224 million services. This gives an average cost of $371 per service. The cost of a visit has therefore been rounded to $400. Figure 4.3 plots the benefit estimate for additional round trip, $\frac{\partial MDA}{\partial Lgpv} \times \$245{,}000 - \$400$. It indicates that the longevity benefit from an additional GP visit is highest for people with very few visits per year and falls to around zero just over 5.5, which is approaching the Australia-wide average of 6.4 from Table 4.2.

Figure 4.3 Benefit from one additional GPV visit as a function of GP visits per person per year



Although the 3 other variables in the model do not appear in the benefit formula, they perform an important role in the model of taking out some of the other factors that affect longevity and would have biased the estimated benefit upward.[23]

As the curve in Figure 4.3 is almost a straight line, the relationship can be approximated by

$$Benefit = 9921 - 1784\;gpv$$

for *gpv* values up to 5.5. If local data on average GPV visits per annum is unavailable, an average can be applied calculated from the average numbers of GP visits per annum in Table 4.2. For the Remote and Very Remote RAs the average number of GP visits is 3.9, which gives a benefit of approximately $3,000 for one additional visit. For Outer and Inner Regional RAs, the benefit value is zero.

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23 Omitting the 3 other variables, regression of $log(MDA) = \beta_0 + \beta_1 gpv + \beta_2 gpv^2$ for the 207 observations yielded an r-squared of 0.651, and coefficient estimates of β_1 = 0.0618 and β_2 = –0.0049. The estimated benefit from one additional GP visit would then be $4,912 at 3.9 GP visits per annum compared with $2,962 for the preferred model. In other words, addition of the other variables to the regression reduced the benefit estimate by 40%.

The only comparable value we have been able to find in the literature is from Godavarthy et al. (2014) of $713 in 2011 US dollars. This translates to around $1,600 in 2024 Australian dollars [× 1.39 for US inflation / 0.63 USD/AUD]. Recalling that a GP visit in the present context is accompanied by 0.5 of a non-GP primary health care trip, the equivalent value from Godavarthy is of the order of $2,400. So our recommended value of health trip of A$3000 for remote areas is within the plausible range. Godavarthy et al.'s methodology is described in Appendix A.3.

Our recommended benefit value from an additional GP visit considers only the potential increase in an individual's lifespan and not quality of life outcomes for the individual, nor cost savings to society where early intervention reduces the need for more expensive treatments. As the mortality data includes suicides, mental health benefits are, to a degree, covered.

Another source of health benefits from improvements to roads in remote and regional areas would be travel time savings for emergency services trips, which could improve recovery outcomes. However, this benefit applies to existing trips, not induced trips, and so falls outside of the scope of the social benefit concept in this report.

4.5 Employment benefits

A reduction in the generalised cost of commuting could lead some workers to decide to work longer hours, or encourage some under-engaged or disengaged workforce members into active employment. Their individual decisions will be made weighing up their disutility and other private costs associated with the job, including the generalised cost of commuting, against the after-tax remuneration received. Conventional CBA fully captures the net benefit to the individual in the consumers' surplus benefit for induced trips, calculated by applying the rule-of-half. The value of the output produced by the additional labour provided is the pre-tax wage rate, based on the idea from economic theory that, in a competitive market, an employer will employ workers up to the point where their value of marginal product equals the cost to the employer. Income tax paid by the employee and payroll tax paid by the employer create a 'wedge' between the value of the additional output and workers' remuneration. The tax paid is a benefit to society which conventional CBA does not capture. This is classed as a WEB, termed WB2 – labour market and tax impacts. Methods and parameter values for estimating WEBs in Australian cities are in ATAP (2023 T3).

Unemployment benefits can also create a wedge between the value of output from additional labour and the net reward to the employee, however, they are not considered to contribute to WB2. Unemployment benefits create a distortion related to changing the level of unemployment, which is not the same as increasing labour supply (ATAP 2023 T3, p. 18). Furthermore, the financial incentive for an unemployed worker not to work created by unemployment benefits, may well be offset by the disutility of the requirements to apply for jobs imposed by the Australian Government to continue to receive the benefits.

The methodology to estimate the additional tax receipts to federal and state governments as a result of an additional employment trip was as follows, with the workings shown in Table 4.5. The methodology is that in ATAP (2023 T3).

- Obtain from ABS 2021 Census data total personal income by RA for the working age population (ages 15 to 64) as recommended in ATAP (2023 T3, p. 22). This is given by numbers of persons in each of 14 income bands for each RA category (excluding negative income, nil income, not stated and not applicable). Persons in major cities were excluded and a single benefit parameter was calculated for induced trips outside of major cities.[24] (columns 1 and 2 of Table 4.5)

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[24] Population-weighted average annual earnings for the 5 RAs for the working age population adjusted to 2024 earnings were Major Cities $77 000; Inner Regional $66 000; Outer Regional $66 000; Remote $76 000; Very Remote $64 000. There appears to be a clear distinction between major cities and the rest of Austalia after taking into account the affect of high earnings for workers in the mining industry in remote areas. It was therefore decided to combine the RAs outside major cities to produce a single benefit parameter.

- Adjust the mid-point earnings for each band by the index of earnings (ABS Earnings; Persons; Full Time; Adult; Ordinary time earnings) from 2021 to 2024 (an increase of 10.7%) (column 3)
- Multiply the indexed mid-point earnings for each band by 0.7 and 0.8. ATAP (2023 T3, p. 21) recommends adjusting earnings downward by a factor of 0.7 because the marginal worker works fewer hours and by a factor of 0.8 because the marginal worker earns less than the average worker. (column 3)
- Estimate the earnings per round trip for the marginal worker by dividing by 190 round trips per year = 45 weeks × 5 days per week × 0.844 adjustment for the fewer hours worked by the marginal worker. It is assumed that travel does not occur for 4 weeks of the year due to annual leave and a further 3 weeks for public holidays and sick leave. The marginal worker is assumed to work 0.7 of the hours worked by the average worker. This is assumed to involve 0.844 fewer trips and 0.829 fewer hours per day, where 0.844 × 0.829= 0.700. (column 4)
- Obtain the marginal tax rate for each income band after the previous adjustments. These are 0% up to $18,200, 16% from $18,201 to $45,000 and 30% from $45,001 to $135,000. Annual earnings adjusted for the marginal worker do not go beyond this threshold. Add on the 2% Medicare levy payable on incomes above $26,000. (column 5)
- Estimate the tax paid for an additional trip comprised of income tax paid by the worker at the marginal tax rate plus 2.7% payroll tax (ATAP 2023 T3, p. 23). (column 6)
- Take the population weighted average of the tax paid for an additional trip, which works out at $54.85 per trip as the tax take on the value of output from an additional round trip for employment purposes.

Based on 3 sources (McMahon 2004, p 244; Chapman & Lounkaew 2015; PwC 2019), the education benefits were grossed up by 30% to take account of non-pecuniary externalities from education from improved outcomes to governments and broader society in relation to health, crime and social cohesion. The same non-pecuniary externalities would arise from increased employment and, in the case of education, the 30% was applied to before-tax earnings. The weighted average earnings per trip of $202.14 was multiplied by 30% to obtain $60.64 as the social value of non-pecuniary externalities from increased employment. Adding this to WEB of $54.85, the social benefit for an additional round trip for employment purposes is $115.49, or $115 rounded.

Table 4.5 Estimation of social benefit from an additional employment trip

Income band (weekly)	Mid-point income (weekly)	Workers outside major cities	Annual income for marginal worker adjusted to 2024	Earnings per round trip	Marginal tax rate	Tax on earnings from an additional trip
	(1)	(2)	(3)	(4)	(5)	(6)
$1-$149	$75	153,787	$2,418	$13	0%	$0.34
$150-$299	$225	211,754	$7,255	$38	0%	$1.03
$300-$399	$350	234,824	$11,285	$59	0%	$1.60
$400-$499	$450	240,707	$14,509	$76	0%	$2.06
$500-$649	$575	300,174	$18,540	$98	0%	$2.63
$650-$799	$725	325,406	$23,376	$123	16%	$23.01
$800-$999	$900	407,993	$29,019	$153	18%	$31.62
$1,000-$1,249	$1,125	442,300	$36,273	$191	18%	$39.52
$1,250-$1,499	$1,375	315,967	$44,334	$233	18%	$48.30
$1,500-$1,749	$1,625	197,724	$52,395	$276	32%	$95.69
$1,750-$1,999	$1,875	270,876	$60,456	$318	32%	$110.41
$2,000-$2,999	$2,500	313,050	$80,608	$424	32%	$147.21
$3,000-$3,499	$3,250	63,175	$104,790	$552	32%	$191.38
$3,500 or more	$5,250	90,634	$169,276	$891	39%	$371.52
Total		3,568,371	$43,527*	$202*		$54.85*

Notes: Column 3 = column 1 × 52 weeks per year × 0.7 × 0.8 × 1.10725
Column 4 = column 3 / 190 round trips per year
Column 5 = Marginal tax rate + 2% Medicare levy for incomes above $26,000
Column 6 = column 4 × (column 5 + 2.7% payroll tax).
* population weighted average using population proportions from column 2 for the weights

4.6 Conclusion

Table 4.6 summarises the recommended benefit values for the different trip purposes for which a methodology has been provided to estimate induced trips. The values are indicative but are the best that can be obtained within the resources and scope of the present report. The worked examples in Appendix B illustrate how they can be combined with induced traffic estimates. It should be noted that the social benefit amounts for induced education and health trips include the rule-of-half benefit, but not so for induced employment trips.

Table 4.6 Summary of recommended social benefit values (2024 prices)

Trip purpose	Benefit per additional round trip			
Discount rate	3%	4%	5%	7%
Early childhood education	$71	$48	$35	$5
Primary and secondary education	$628	$468	$349	$190
Tertiary education	$736	$517	$356	$149
Health	Either: • *Max* ($9,921 – $1,784 × average number of GP visits per annum, 0) or • $3,000 per round trip for remote and Very Remote RAs; zero for outer regional and Inner Regional RAs			
Employment	$115			

5. Wider economic benefits

5.1 Introduction

WEBs arise from market imperfections arising from economies of scale and scope, external economies, taxation and imperfect competition.[25] Market imperfections cause market prices, the measuring rod for social value, to differ from marginal social costs. WEBs are additional to benefits estimated in conventional CBAs (ATAP 2023 T3, p. 2). The underlying ideas originated in UK DETR (1999) and were developed by the UK Department for Transport and others in the UK. The government discussion paper, UK DfT (2005), identified 4 types of WEB. Three of these have been accepted as being likely to be of significant size for major transport projects in cities, in particular, for 'city-shaping projects' that induce significant land-use change. Recommended methodologies and parameter values to estimate them are set out in CBA guidelines for UK, Australia (ATAP 2023 T3) and New Zealand.

The 3 accepted types of WEBs arise from:

- agglomeration economies — productivity gains from firms clustering in the same area (WB1)
- labour market and tax impacts — productivity gains from increased labour supply and moves to more productive jobs accruing to governments via the taxation system (WB2)
- output changes in imperfectly competitive markets — increased profits to firms with some degree of market power (WB3).

Where road improvements in remote and regional areas result in additional trips for employment purposes, Chapter 4 of this report provides a value with which to estimate the WEB from increased income and payroll taxes accruing to governments (WB2).

A fourth type of WEB (WB4), identified in UK DfT (2005), arises from a transport improvement exposing a local monopoly or oligopoly to competition forcing it lower prices. UK DfT(2005) did not expect this effect to be significant in a country like the UK, being densely-populated with extensive transport infrastructure. ATAP (2023 T3) took the same position for Australian cities and regional centres, but conceded that it may be relevant in some cases for remote parts of Australia. ATAP (2023 T3) was not able to offer a methodology to estimate WB4 because none has been developed.

Laird & Mackie (2014) assessed the case for WEBs of each type to exist in remote rural areas as well as some additional types of WEB. Starting with the 4 types of WEB in UK DfT (2005), and moving on the 2 other types of WEB identified by Laird & Mackie (2014), this chapter discusses their potential relevance for assessing road improvements in remote and regional areas and recommends methodologies for estimating them.

5.2 Agglomeration (WB1)

Agglomeration impacts refers to benefits that flow to firms and workers from locating in close proximity to one another (agglomerating or clustering). Duranton and Puga (2004) categorise the sources of agglomeration economics into sharing (greater specialisation, sharing indivisible goods and facilities, sharing risks), matching (workers better matched to job requirements) and learning (generation, diffusion and accumulation of knowledge). Agglomeration results in an improvement of productivity for firms clustered together. Since one firm confers a benefit on another firm, there is an externality. Agglomeration WEBs are estimated from changes in 'effective densities', an accessibility measure.

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[25] WEBs are sometimes referred to as 'Wider Economic Impacts' (WEIs). The use of the WEIs terminology acknowledges that not all transport projects generate positive benefits. The ATAP Guidelines uses the term WEBs noting that WEBs can be both positive and negative. Use of the WEBs terminology avoids possible confusion with secondary economic impacts of projects that are not legitimate inclusions in CBAs (ATAP 2023 T3, p. 1).

As remote and regional areas have much lower population densities than urban areas, agglomeration economies are less likely to be relevant to them. An exception might be where a new major high-speed road or rail link passes through a region resulting in a major improvement in access to a large urban centre. While the impact on effective density for the large urban area would be small or negligible, the impact on the effective density of the regional centre would be large (Laird & Mackie 2014; Laird 2018). For cases where a remote or regional area experiences a step change in accessibility to an urban centre, the standard methodology for estimating agglomeration WEBs in ATAP (2023 T3) could be applied. However, it is unlikely to be worth the effort because the productivity improvement from agglomeration benefits is likely be very small in proportion to the total benefits of the major high-speed link being assessed (Laird 2018).

For road projects in remote and regional areas, we conclude that agglomeration benefits are of negligible size and not worth the effort of estimation.

5.3 Labour taxes (WB2)

The labour tax WEB was addressed in Chapter 4 as a social benefit from additional trips for employment reasons. It can be added that the labour tax benefit only occurs where there is a genuine increase in labour supply. If increased employment for people commuting from the location benefitting from the transport improvement is at the expense of others who lose their job or work fewer hours (displacement effects), there is no net benefit (Laird & Mackie 2014; Laird 2018).

The method for estimating induced trips for employment purposes in Chapter 3 has the potential to estimate increased employment trips from the origin SA1 benefitting from the road improvement that displace employment from other origin SA1s. Analysts estimating social benefits from additional employment trips (both the labour tax WEB and the positive externalities) should assess the possibility of partial or complete displacement and adjust the benefit estimate downward accordingly. However, it is likely that the smallness of the number of induced trips will ensure that inclusion or otherwise of employment social benefits will have little effect on overall benefits.

5.4 Output changes in imperfectly competitive markets (WB3)

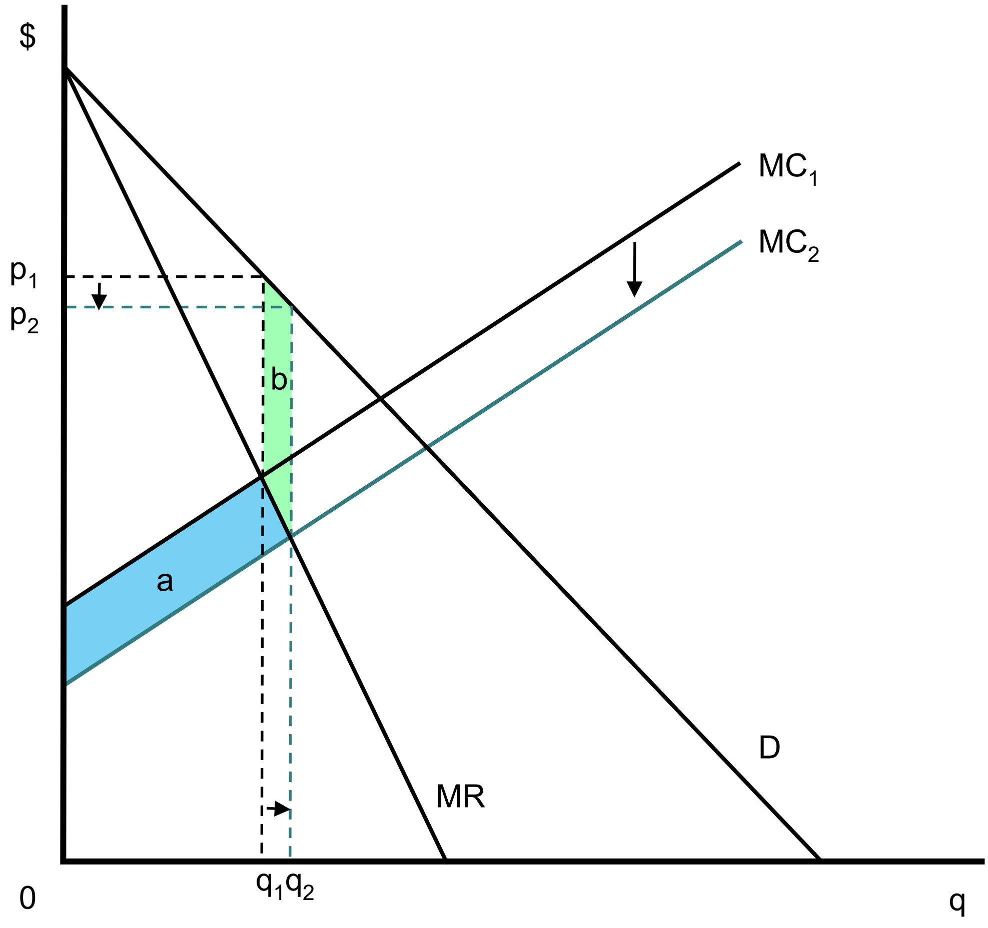
In an imperfectly competitive market, prices can exceed production costs. Firms produce less output than they would under perfect competition because they restrict output to maintain higher prices. The WEB arises where a reduction in transport costs causes an increase in the production or output of goods or services that use transport as an input. Conventional CBA fully captures the gains to producers and consumers from the transport cost reduction in relation to the lower cost to supply the existing output and the consumers' surplus gain from the additional output. However, the existence of a price above marginal social cost under imperfect competition implies that consumers' valuations or willingness to pay for the additional output produced exceeds the marginal social cost of producing that output. Thus, there is an economic welfare gain not captured by conventional CBA. This welfare gain accrues to the firm as profit earned on the increased output. Since CBA adds together costs and benefits regardless of to whom they accrue, increased profits to producers are just as much a benefit as gains to consumers (ATAP 2023 T3).

Figure 5.1, from ATAP (2023 T3), illustrates the WEB and how to estimate it using the standard textbook monopoly pricing model. The diagram refers to the market for a good or service for which transport is an input. The vertical axis shows prices and costs (not generalised costs of transport as in Chapter 2) of the good or service and the horizonal axis shows units of the good or service (not traffic or trips).

Maximum profit occurs at the level of output where marginal cost (MC) equals marginal revenue (MR). Price is read off the demand curve at the point where consumers will purchase all the output produced. The transport project reduces input costs, shifting the MC curve down from MC_1 to MC_2. The profit maximising output increases from q_1 to q_2 and price falls from p_1 to p_2. Area *a*, between the base-case and project-case MC curves is the saving in generalised costs (time and vehicle operating cost savings) for business cars and freight that are inputs to production. It is part of the consumers' surplus area estimated by a conventional CBA. Area *b* is the WEB — the difference between consumers' WTP for the additional output and the cost of producing it. Area *b* accrues to the firm as additional profit. The 'uprate factor' is the ratio of the value of the WEB, area *b*, to the conventional CBA benefit, area *a*. It can be estimated as the price–marginal cost mark-up times the elasticity of demand for the product, η.[26]

$$Uprate\ factor = \frac{b}{a} \approx \frac{(p - MC)}{p}\eta$$

Figure 5.1 Monopoly diagram with output change



Source: ATAP (2023 T3).

Note that the transport improvement does not change the level of competition in product markets or reduce price mark-ups. This is an important difference between WB3 and WB4, the subject of the next section, where the road project improves competition and reduces price mark-ups.

Estimation of WB3 requires an estimate of the total benefit from savings in private generalised costs of business and freight trips due to the transport project. Only trips paid for by firms or employers should be included — not non-work travel or commuting trips. Relevant passenger trips are those for business purposes, whether by car or public transport. The benefit accruing to business and freight trips is then multiplied by the 'uprate factor'.

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26 The derivation is as follows.

Uprate factor $= \frac{b}{a} = \frac{(p-MC)\cdot dq}{-q\cdot dMC}$. Assume $dMC = dp$, which is an approximation. Uprate factor $= -\frac{(p-MC)}{q}\cdot\frac{dq}{dp}$

Demand elasticity (made positive for simplicity): $\eta = -\frac{dq}{dp}\frac{p}{q}$, from which $-\frac{dq}{dp}\frac{1}{q} = \frac{\eta}{p}$. Substituting this into the uprate factor formula:

Uprate factor $= \frac{b}{a} = \frac{(p-MC)}{p}\eta$

The uprate factor recommended in ATAP (2023 T3) is 0.1, based on indicative values of a 20% mark-up and –0.5 price elasticity of demand for goods and services averaged across all industries and cities.[27] ATAP (2023 T3) recommended that WB3 only be estimated in cases where agglomeration and labour tax WEBs are also estimated. The reasons given were that it is the smallest of the 3 WEB types and the estimates are highly approximate. The simple calculation method makes no distinction between locations and industries. The research into price–cost mark-ups of Australian firms needed to derive robust parameter values does not exist.

Laird & Mackie (2014) argued that market power tends to be higher in remote rural areas than elsewhere because local market size is small, restricting the number of firms that can co-exist. The retail sector is one where firms are likely to have a degree of market power. Price–cost mark-ups are therefore likely to be higher for retailing in remote areas than in other parts of the economy. However, the evidence is limited. The fact that prices are higher for the same product in a remote town compared with a city could reflect higher transport and distribution costs and lower turnover rather than market power.

BITRE (2008) obtained prices of food and non-food supermarket products from data directly recorded in 236 supermarkets in 132 locations across Australia throughout 2005 and 2006 and calculated a supermarket index value for each location. Higher index values were found to be mostly confined to locations with fewer than 5,000 people. Pricing by the major chain stores did not appear to be affected by the remoteness of the stores or the population sizes of the towns in which there were situated. This confirmed the existence of uniform pricing policies by the major chains. The presence of a major chain store in a town supermarket index tended to keep prices down. The average price premium in stores in locations without access to a major chain store was 17% above the average major chain store. Some of the highest prices and lowest availabilities of products were found to be at Indigenous communities in Western Australia and Northern Territory.

The Australian Competition and Consumer Commission (ACCC) inquiry into the competitiveness of retail prices for standard groceries found that grocery prices differ across regions and states, but many of these differences are the result of cost differences in sourcing and retailing groceries as well as local demand and competitive conditions (ACCC 2008, p 69). The ACCC monitors fuel prices and reported on its website that fuel prices are generally higher in regional locations due to fewer people and less demand resulting in fewer outlets, leading to less competition.

The transport cost reductions from a road improvement project benefit freight travelling out of remote and regional areas as well as inbound freight. WB3 benefits are therefore split between local and non-local firms. While mark-ups may be higher in remote and regional areas due to lower levels of competition, the mark-ups for non-local firms sourcing inputs from remote and regional areas are likely to be nearer the national average. The ideal price–cost mark-up from which to calculate the uprate factor would lie somewhere between the national average and the higher average for remote and regional areas. In the absence of the detailed research into mark-ups, it is recommended that the standard approach to estimating the imperfect competition WEB (WB3) in ATAP (2023 T3) be applied to road projects in remote and regional areas with the uprate factor of 0.1. Higher mark-ups in remote and regional area mean that this is likely to be on the conservative side.

5.5 Change in competition (WB4)

In an isolated community where high transport costs make non-locally sourced goods and services expensive, a firm may be have a local monopoly enabling it to charge a price significantly above efficient production costs. Building a new transport link, or greatly improving an existing link to the rest of the economy can introduce competition from outside. The local monopolist may be driven to reduce prices and improve production efficiency. The benefits to consumers in the area may outweigh the losses to the previously protected firms in the area creating a net benefit to society as a whole.

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[27] The 10% uprate factor in ATAP (2023 T3) was the recommended value in UK guidelines until recently. UK DfT (2025b, p. 35) recommends a 13.4% uprate factor. UK DfT (2025b, p. 35) also allows WB3 to be estimated directly from economic modelling provided the estimate from modelling is reported alongside the estimate from the simple uprate factor method.

Figure 5.2 shows the textbook monopoly diagram as in Figure 5.1 but with some additions. For simplicity, marginal cost is drawn as being constant. The marginal cost is for local production and is assumed not to be affected by the transport improvement. The monopoly price is p_m. However, the firm is unable to charge this because the same product can be imported into the town or locality at a price $p_1 = c + t_1$, where t_1 is the transport cost from the nearest alternative source of the product in the base case and c is the difference between the price and the transport cost, assumed to be the production cost. It is further assumed that the good or service is available from outside in perfectly elastic supply sold at a price equal to cost, including a normal profit. The local firm has no choice but to charge a price just below p_1 and in doing so, captures the entire local market. It is assumed the product sold by the local firm and the imported product are perfect substitutes. More complex models could be developed in which there is a degree of product differentiation.

A road improvement lowers the transport cost to the project-case value of t_2 forcing the local firm to drop its price to $p_2 = c + t_2$. The quantity sold in the local market increases from q_1 to q_2. The local firm continues to supply the whole market by just undercutting the price of the imported product. Area *a* is a transfer from the local firm to consumers and so is not counted as a benefit in the CBA of the road improvement. Area *b*, the gain in WTP (area under the demand curve) minus the production cost for the additional goods sold, is a WEB. The firm loses area *a* and gains area *b*.

The benefit, area *b*, is $\left[\frac{1}{2}(p_1 + p_2) - c\right] \cdot \Delta q$ where $\Delta q = q_2 - q_1$, or, more simply, $\frac{1}{2}(t_1 + t_2) \cdot \Delta q$. The increase in the quantity of the good or service, Δq, could be estimated by applying a demand elasticity to the base-case price and quantity. The –0.5 demand elasticity used to estimate that uprate factor for WB3, would be a conservative default value.

A variation shown in Figure 5.3 occurs where the base-case selling price of the imported good or service, including the transport cost, is above the monopoly price, p_m, and the road improvement brings the cost of the imported good below p_m forcing the local monopolist to reduce their price. In this case, the price fall from p_m to $p_2 = c + t_2$ is less than the full extent of the transport cost reduction. The benefit is $\left[\frac{1}{2}(p_m + p_2) - c\right] \cdot \Delta q$. Letting the difference between the base-case import price and the local monopoly price be $d = p_1 - p_m$ the benefit formula becomes $\frac{1}{2}(t_1 + t_2 - d) \cdot \Delta q$.

For small changes in transport costs, the benefit could be estimated as

$$\frac{(p - MC)}{p} \cdot \eta \cdot q \cdot (t_1 - t_2)$$

where $\frac{(p-MC)}{p}$ is the price–marginal cost mark-up and q is the base-case quantity of the good or service sold by the monopolist.[28]

Note that if *both* the base-case and project-case prices for the imported good are above the monopoly price, there will be no price reduction in the project case and hence no additional benefit.

A CBA claiming this benefit would have to demonstrate that:

- for a particular good or service, there is only one or a few suppliers in the local area
- the price of the local good or service is:
  - significantly above the cost of obtaining an identical or near-identical good or service from another location or locations excluding transport costs, but
  - at or just below the cost of the imported alternative such that there is little or no importation from other sources

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[28] The derivation is as follows. Demand elasticity for the good or service (made positive for simplicity) is: $\eta = -\frac{dq}{dp}\frac{p}{q}$. For a small change in quantity of the product, the benefit is

$$(p - MC) \cdot dq = (p - MC) \cdot \frac{dq}{-dp}\frac{p}{q}\frac{q}{p} \cdot (-dp) = \frac{(p - MC)}{p} \cdot \eta \cdot q \cdot (t_1 - t_2)$$

Figure 5.2 Monopoly with competition from imports: base-case price below monopoly price

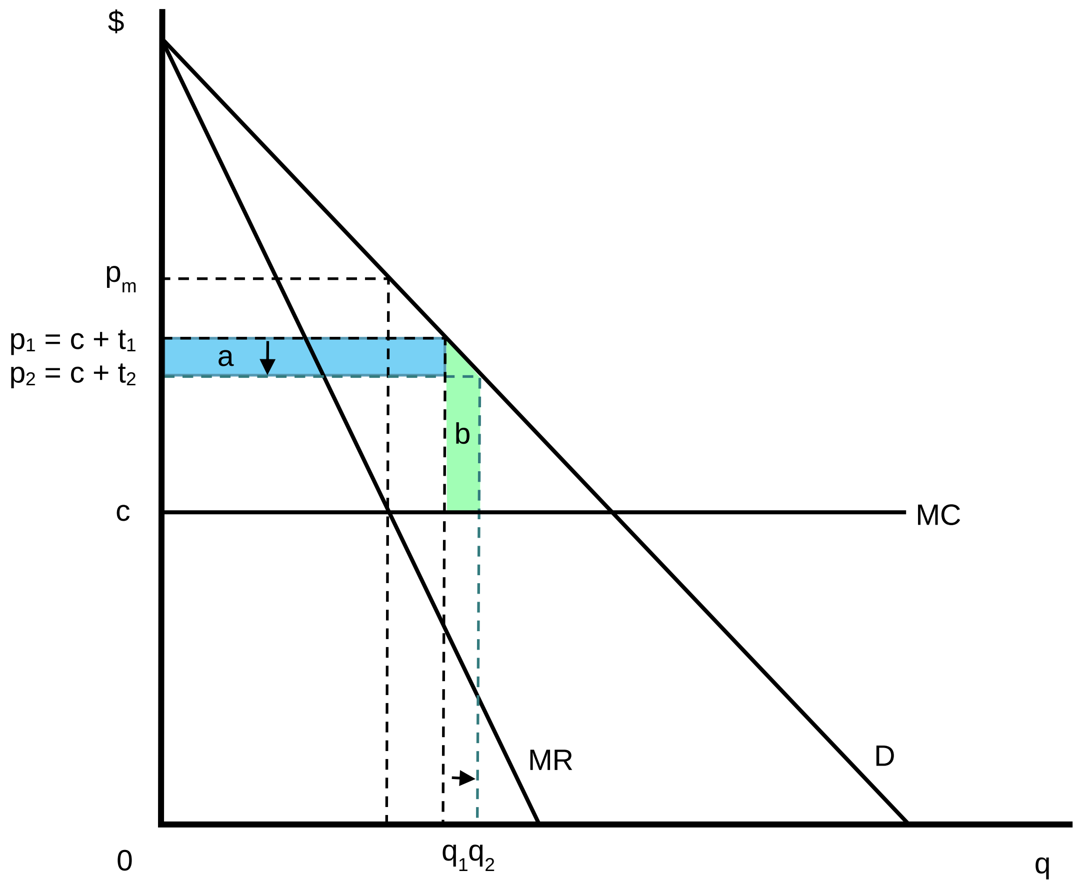
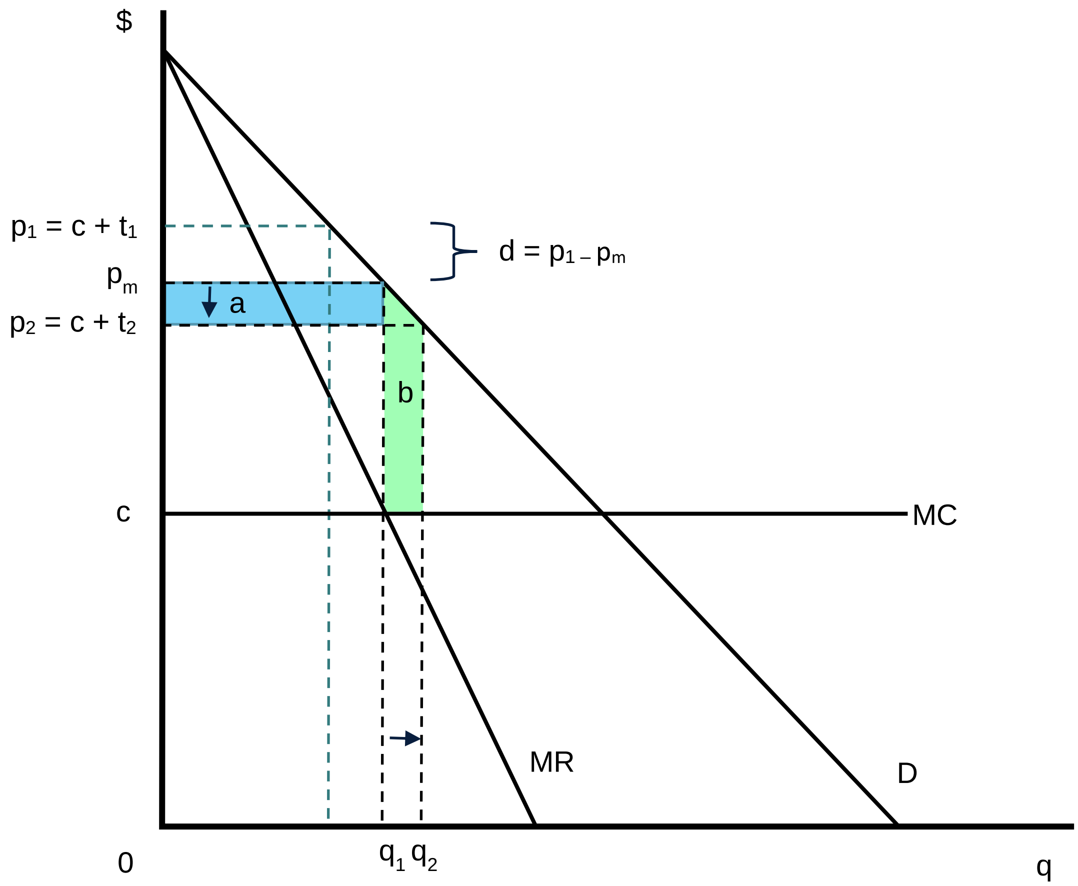


Figure 5.3 Monopoly with competition from imports: base-case price above monopoly price



- the reduction in transport costs resulting from the project being assessed will lower the cost of importing the good or service to a level below the current local price.

Part of the surplus accruing to the monopolist in the base case, $(p_1 - c) \cdot q_1$ in Figure 5.2, could be consumed by higher production costs due to lack of incentive to produce efficiently. If production costs were reduced as a result of competition from imported goods or services, there would be a benefit associated with the base-case output, q_1. However, inefficiency in production by the monopolist would be difficult to detect because costs are not public information. If evidence could be found, the benefit would be the cost reduction times q_1.

The analysis here refers to a good sold in remote location that could be imported into the remote location. It also applies to a service supplied in the location, where local people would have to travel some distance to obtain the same service, for example, a motor mechanic, solicitor or hairdresser. WB3 and WB4 could occur together where a retailer charges a high price–cost mark-up and a road improvement both reduces their costs and forces them to reduce their mark-up.

Information required to estimate WB4 includes price data for a range of goods and services in multiple locations. It will therefore be difficult for an analyst to make a case for including WB4 in a CBA of a remote or regional road improvement.

5.6 Monopsony labour markets

A 'monopsony' occurs where there is one buyer for the produce of a large number of sellers. The typical labour market monopsony is a mining or mill town in the early days of the industrial revolution in the UK. Improved access for workers to jobs in other locations can reduce the monopsony power of a local employer.

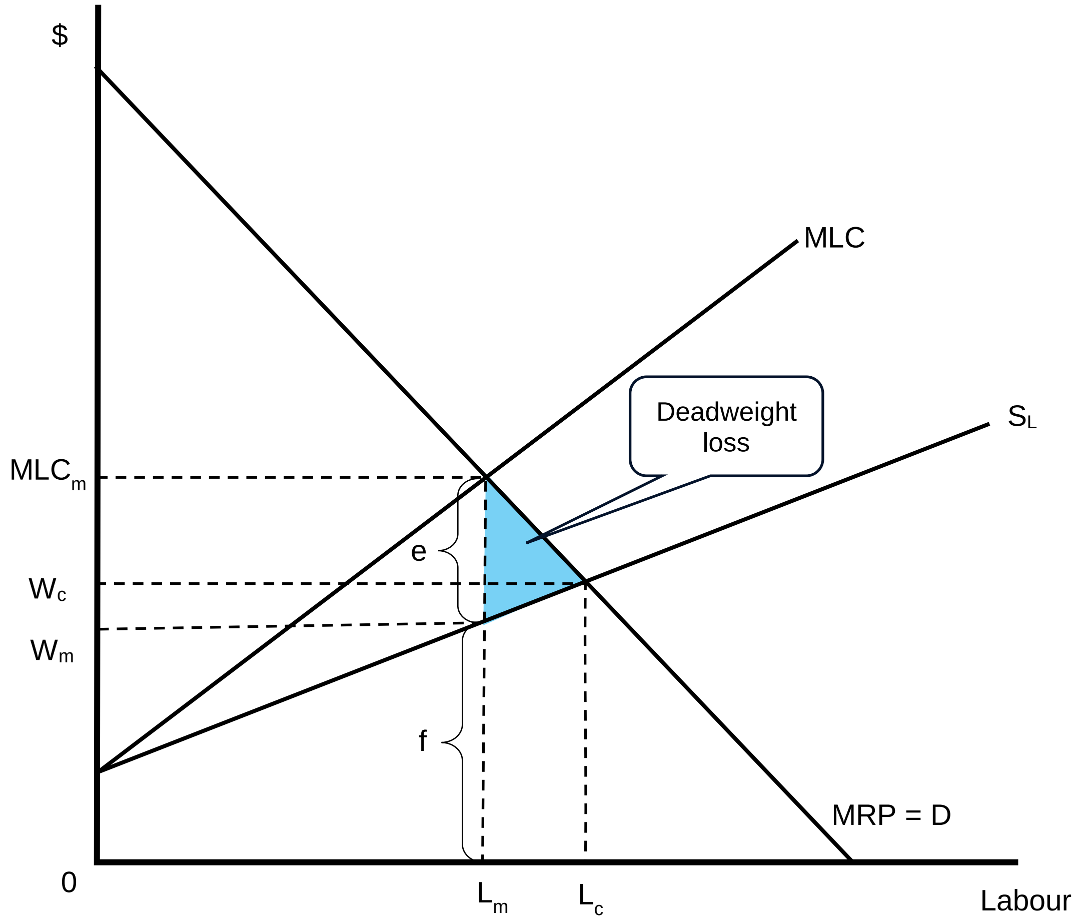
The classical monopsony model is shown in Figure 5.4. It represents the profit-maximising position for a firm with a monopsony in the labour market. The firm faces an upward sloping supply curve for labour, S_L. In a perfectly competitive labour market, the labour supply curve faced by the firm would be perfectly elastic. The firm would employ labour up to the point where the marginal revenue product (MRP) equals the wage rate, shown in Figure 5.4 as employment L_c and wage W_c. The MRP is the marginal product of labour times the marginal revenue from selling the product. Hence, it is the revenue the firm would earn from employing an additional worker. The MRP curve is the firm's demand curve for labour.

In a monopsony, the firm's employment decision is based on the marginal labour cost (MLC) it faces. If the firm offers a higher wage to attract more employees, it must pay that wage to *all* employees, not just the additional employees. So the MLC to the firm exceeds the wage rate. With a linear supply curve, $W = a + bL$, the total wage bill for the employer is $WL = aL + bL^2$. Then $MLC = \frac{d(WL)}{dL} = a + 2bL$. The monopsonist firm will employ labour up the point where *MLC* = *MRP*, that is, where the cost of an additional worker to the firm equals the additional revenue for selling the output they produce. The monopsony levels of employment and wages, shown in Figure 5.4 as L_m and W_m, respectively, are below the competitive levels.

Letting *R(L)* be the firm's revenue function net of other input costs and *W(L)* the labour supply curve, the profit maximising firm will set its employment level to maximise $R(L) - W(L) \cdot L$. The first order condition is $\frac{dR}{dL} - \left(W + \frac{dW}{dL}L\right) = 0$. This can be rearranged to give $E = \frac{MRP - W}{W} = \frac{1}{\eta}$ where $MRP = \frac{dR}{dL}$, $\eta = \frac{dL}{dW}\frac{W}{L}$ the elasticity of supply of labour, and *E* is a 'measure of exploitation' (Boal and Ransom 1997; Manning 2003a, p. 30). The measure of exploitation is shown in Figure 5.4 as the ratio of *e* to *f*.

The coloured triangle is the deadweight loss, that is, the cost of the loss of economic efficiency. The area under the MRP curve is total social welfare in the market. The area under the labour supply curve is the opportunity cost of labour in the market. Maximum welfare occurs at the competitive equilibrium. The deadweight loss occurs for the employment supressed by the monopsony, L_mL_c. It equals the difference between the value society loses, measured by the area under the MRP curve, and the opportunity cost of labour saved, measured by the area under the labour supply curve.

Figure 5.4 Wage and employment determination under monopsony



There are few labour markets with just one employer or a small number in collusion, and workers have the ability to move, causing economists to be sceptical of the relevance of classical monopsony models. However, modern theories of monopsony in labour markets emphasise that employers do not have to be large in relation to labour markets to have some market power.

One group of monopsony models assumes workers have full information and no costs of changing jobs but jobs are differentiated in some way. Geographical location is one form of differentiation. Employers do not exist at all points, which is a source of monopsony power. As the employer offers a higher wage, workers are willing to commute longer distances, increasing the choice of workers. All labour markets are therefore monopsonistic in some degree (Manning 2003b). The less dense the number of employers, the greater their market power. Hence, in rural areas, labour markets tend to be more concentrated and employers face labour supply curves with lower elasticities (Manning 2010; Araki et al. 2022).

Another group of modern theories is based on ‘search costs’. It takes time and money for workers to change jobs. Even if there are many jobs in a worker’s neighbourhood, only a small percentage of them become vacant at any one time (Manning 2003b). The labour market is therefore, effectively, ‘thin’. If the employer reduces wages by a small amount, it does not immediately lose all its existing workers, as would occur in a perfectly competitive labour market (Manning 2021, pp. 3-4). Rather, the employer experiences a decrease in the rate of job applications and a higher rate of separations. Employers then have some market power over wage rates and can restrict employment and wages below the levels that would occur under a competitive market.

Laird & Mackie (2014, p. 95) cite evidence that thin labour markets are particularly relevant in remote areas where there is limited choice of employers for workers. There are few jobs advertised. Often vacancies are not advertised but are filled through contacts and networks. From a survey of unemployed jobseekers in rural Scotland, McQuaid et al. (2004, cited in Laird & Mackie 2014) found that people with low educational attainment, the long-term unemployed, young people and those perceiving their information and communication technology skills to be ‘poor’, were less likely to use the internet. Although respondents in rural areas were more likely to use information and communication technology to look for work, they also pointed to the overriding importance of informal social networks as a means of sharing job information in remote communities.

An indicator of thin labour markets is the extent to which wages adjust to compensate workers for commuting costs. In a competitive labour market, wages will be the same for workers of a given ability at a given employment location even if there are differences in travel costs. The search model of monopsony in labour markets predicts that workers with higher travel costs will receive higher wages. There will be a wage gradient for compensating workers for longer commutes (Manning 2003b).

Booth and Katic (2011) estimated a labour supply elasticity for Australian firms of around 0.71, which is quite close to Manning's (2003a, p. 105) estimate for the UK of 0.75. An elasticity of 0.71 implies that the exploitation measure is 1.41, that is, the gap between the MLC and the wage rate is 1.41 times the wage rate, which seems surprisingly high. However, there is a wide range of estimates of the elasticity of supply of labour faced by individual firms. Elsewhere, Manning (2003a, p. 80) stated that 2 to 5 is a reasonable range, implying exploitation measures of 0.5 to 0.2. A meta-analysis by Sokolova and Sorensen (2021) covering 1,320 estimates of the labour supply elasticity from 53 studies found estimates from below zero to 50. They suggested a best-practice estimate of 7.1 (p. 48) worldwide. However, they found that that the mean and median for developing countries were larger than for European countries and other advanced economies, and that the latter group, comprising Australia, Canada and US had a lower mean than Europe.

To estimate the WEB from thin labour markets for 4 case studies from Scotland, Laird & Mackie (2014) estimated the number of jobs created to which an additional surplus could be attached. This required data from economic impact studies that split employment impacts between remote rural areas and elsewhere. They stated that, 'There is no additional welfare benefit to transport user benefits to creating employment in urban or rural areas accessible to an urban area.' The remote rural employment impact was then further split into jobs additional at the national level and those displaced. The WEB per job per year was estimated as the gap between the MRP and S_L curves assuming an elasticity of 5, the upper limit of the range for the UK suggested by Manning (2003a). This implies that the marginal product of labour is 20% above the wage rate. This 20%, accruing to workers, is the WEB.

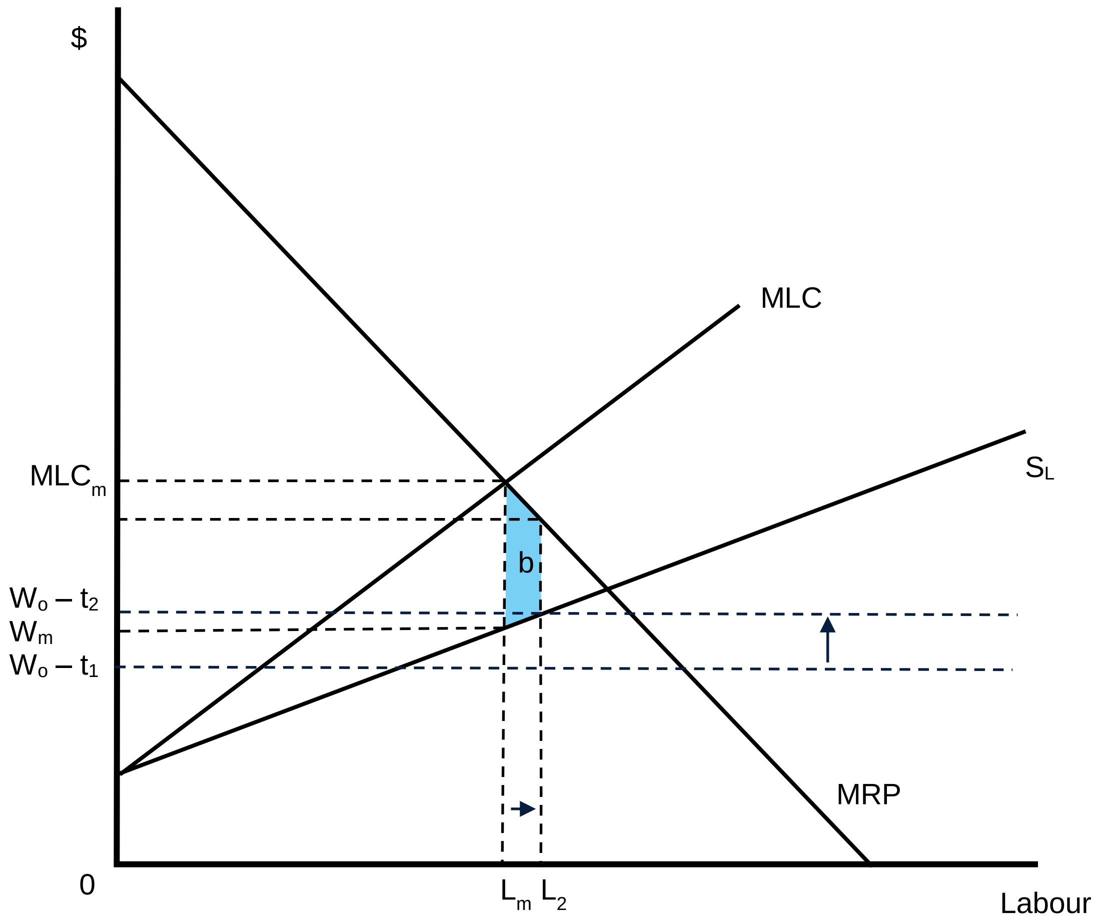
Figure 5.5 shows how a road improvement could give rise to a WEB in a monopsony labour market. In Figure 5.5, a wage of W_o is available at an outside location, but after incurring the transport costs in the base case, workers are left with $W_o - t_1$. As this is below the wage on offer by the monopolist of W_m, no local workers travel outside for employment. The transport cost reduction increases the net earnings for workers commuting to outside employment to $W_o - t_2$, which is above W_m. The opportunity to work outside the locality for a higher wage but with additional commuting costs sets a floor on the wage the local monopolist must pay. This is the mirror image of the scenario in the previous section where the price of imports inclusive of transport costs sets a ceiling on the price a local monopolist can charge. In the project case, the local monopsonist employer pays workers $W_o - t_2$ and employs more of them. The benefit to society is area *b*, the gap between the MLC and labour supply curves for the increased employment, which accrues to employees due to the wage increase.

As noted above, Laird & Mackie (2014) estimated the monopsony labour market WEB as the increase in employment (ΔL) times 20% of the wage rate, assuming an elasticity of 5 for the labour supply curve ($WEB = \Delta L \times W \times 0.2$). They were careful to ensure that only new jobs (additional at the national level) were counted, not displaced jobs.

There is a wide range of elasticity estimates for monopsony labour markets, with the lower-range estimates suggesting implausibly large gaps between the MRP of labour and the wage rate. Laird & Mackie's assumed value of 5 seems a reasonable and conservative value to use in Australian CBAs.

As the supply curve for labour would be before-income tax, the employment social benefit (WB2 plus externalities) for the additional employment can be counted on top of the monopsony labour market WEB.

Figure 5.5 Benefit from transport cost reduction in a monopsony labour market



Conclusions about the monopsony labour market WEB are set out in Section 5.8.

5.7 Involuntary unemployment

Table 3.6 showed that the percentage of the population unemployed is relatively high in SA1s in the Very Remote RA and Figure 3.5 confirmed this for the SA1s with the lowest CI values. The correlation coefficient between the proportion of Indigenous people and proportion of unemployed in each SA1 outside major cities was 0.30 implying that unemployment is particularly high for First Nations people in remote areas.

If improved road access stimulates economic activity, either directly during the construction period or as a result of lower transport costs after the improvement, the opportunity cost of labour (the benefit society forgoes by employing an additional worker) could be below the wage rate. There is therefore a market imperfection. Only the benefit from economic activity in product markets stimulated by the project could be considered to be a WEB, but the shadow wage rate for otherwise unemployed people engaged to construct the project being assessed is addressed in this section because the same model applies to both cases.

The model presented here applies to a very specific form of unemployment, where the number of workers who desire jobs at the wage paid in a particular labour market exceeds the number of workers employers are willing to hire at that wage (Boardman et al. 2018, p. 149). The market should be defined in terms of occupation, skills and location. The wage rate is assumed to be fixed by governments or unions at a level above the rate that would be determined by a competitive labour market.

In Figure 5.6, the lowest upward sloping supply curve represents the value of leisure (VL). Presentation costs (PC) are added on to obtain the *VL + PC* curve. Presentation costs include commuting costs and any other expenses an employee has to incur to hold a job such as work clothing. A person accepting a job forgoes their leisure and incurs the presentation costs. The sum of the value of leisure forgone and presentation costs is the minimum wage a worker will accept for a job and is referred to in economics as the 'reservation wage'.[29]

Imposition of income tax (IT) and payroll tax (PT) creates a wedge between cost incurred by the employer and the wage received by workers, raising the supply curve faced by employers to *VL + PC + IT + PT*.

The base-case demand curve for labour is D_1. With the labour cost to employers (before payroll tax) fixed at *W*, there is an excess supply of labour of $L_3 - L_1$. The road improvement causes an additional quantity of labour to be demanded, $L_2 - L_1$, shifting the demand curve right to D_2. The demand is met by otherwise unemployed workers entering the workforce. The resource or opportunity cost for those workers *appears to be* the coloured area under the *VL + PC* curve, which is the value of their forgone leisure plus presentation costs.

However, Boardman et al. (2018, p. 152) disagree. They argue that there is no basis for assuming that the particular unemployed persons hired will value their leisure as measured by the height of the *VL* curve between L_1 and L_2. The individuals finding employment could have come from anywhere along the supply curve and so have values of leisure anywhere between *e* and *f*. Boardman et al. propose assuming that the workers gaining employment from the project have values of leisure uniformly distributed between *e* and *f*, making the value of forgone leisure (*f* + *e*)/2. Since the value of *e* is unknown, Boardman et al. suggest assuming that the value of leisure at this point is zero. They note that, since the probabilities of illness, divorce and suicide all increase with unemployment, while job skills deteriorate, the lowest value of leisure forgone could be very low for at least some unemployed persons.

The value of forgone leisure for the workers gaining employment from the project then becomes *f*/2. The opportunity cost of unemployed labour or the shadow wage rate is $\frac{f}{2} + PC$.

Since $f = W - PT - IT - PC$, the shadow wage rate is $\frac{1}{2}(W - PT - IT - PC) + PC =$

$$shadow\ wage\ rate = \frac{1}{2}(W - PT - IT + PC)$$

that is: (pre-tax wage – payroll tax – income tax + presentation costs)/2. The coloured area in Figure 5.6 is therefore not the recommended value to use.

The shadow wage rate for unemployed workers should be used in CBAs only in exceptional circumstances: where there is high unemployment of workers of a specific type in a specific region. The shadow wage rate should be applied only to the proportion of workers assumed to be otherwise unemployed ($L_2 - L_1$ in Figure 5.6), not to all workers employed by the project.

There are 2 situations where the shadow wage rate for involuntary employment could be relevant to the CBA of a road improvement in a remote or regional area. The first is where project construction is the source of the additional employment. The shadow wage rate could be used in estimating project construction costs for the proportion of workers who would otherwise be involuntarily unemployed, reducing the social construction cost for the project below the financial construction cost. This is not a WEB because it is an adjustment to project costs, not benefits.

The second situation relates to employment in product markets, not project construction. It occurs after the project has been completed and employment by local firms increases, stimulated by cheaper access to inputs and/or markets for selling outputs. There would be a WEB equal to:

- the cost to employers, assumed to equal the value of marginal product of labour, *W*, minus
- the opportunity cost of unemployed labour or equal to the shadow wage rate.

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[29] In theory, unemployment benefits might be added because a person accepting a job forgoes unemployment benefits in addition to leisure and presentation costs. However, as mentioned in Section 4.5, the financial incentive for an unemployed worker not to work created by unemployment benefits, may well be offset by the disutility of the requirements to apply for jobs imposed by the Australian Government to continue to receive the benefits.

$$Additional\ benefit\ per\ worker = W - \frac{1}{2}(W - PT - IT + PC) =$$

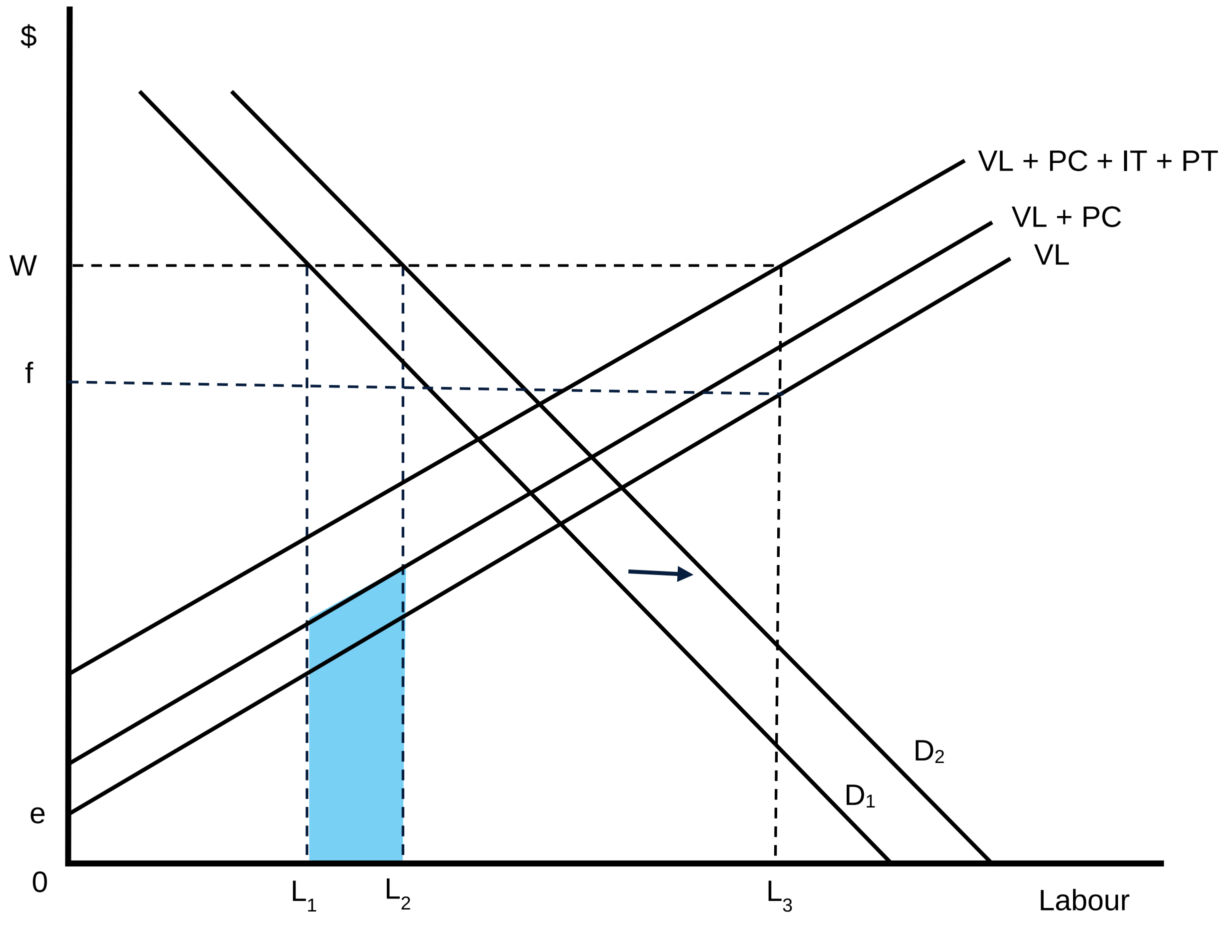
$$= \frac{1}{2}(W + PT + IT - PC)$$

that is: (pre-tax wage + payroll tax + income tax – presentation costs)/2.

Displaced labour from other employment would be deducted from the number of workers for which the extra benefit is counted. The additional taxes accruing to governments (WB2) are already included in the formula for the additional benefit per worker, so the social benefit for employment provided in Chapter 4 is not applicable. The 30% of the gross wage for non-pecuniary externalities could be justified as an additional benefit.

Conclusions about the involuntary employment WEB are set out in Section 5.8.

Figure 5.6 Shadow wage rate for otherwise unemployed labour



5.8 Application of the monopsony labour market and involuntary unemployment WEBs

Applications of the WEBs in the previous 2 sections, arising from monopsony power of employers in local labour markets and involuntary unemployment, both require estimates of the additional employment created as result of a road improvement. The additional employment could be due to one or more of expansion of output by existing firms, new enterprises in existing activities or new enterprises in new activities. For their case studies, Laird & Mackie (2014) relied on economic impact studies to obtain estimates of changes in employment. An economic impact study would only be undertaken for a large project. Such a study is likely to include interviews with producers, consumers and possibly competitors likely to be affected by the road improvement being assessed. An understanding of the markets in which the affected businesses operate is essential for a good quality impact analysis (Laird & Mackie p. 95). Laird and Mackie were careful only to estimate benefits for net new jobs created, that is, not counting displaced jobs. Any employment gains for which WEBs are estimated should be additional at the national level.

The 2 types of labour-market WEB in Sections 5.6 and 5.7 are mutually exclusive. They cannot coexist for the same occupation in the same location. For the monopsony labour market WEB, the additional employment arises from greater competition among employers to attract workers. The additional workers appear because they are offered a higher wage. In the case of involuntary unemployment, additional workers are willing and available, but employers are unwilling to take them on at the wage rate that the employers are required to pay.

Improved road access to a remote or regional area is a two-way street. Not only does it improve access for people in remote and regional areas to larger centres, it also improves access from the large centres to the regions. Local producers could find themselves experiencing greater competition, drawing away economic activity (Laird & Mackie 2014, p. 93). In the involuntary unemployment case, it leads to higher local unemployment, but is unlikely to create a negative WEB (a disbenefit) because the loss of local employment would be offset by higher employment elsewhere.

Unemployed rural workers are likely to migrate away rather than remain and search for jobs (Laird & Mackie 2014, p. 99). UK DfT (2025c, p. 8) remarked that the monopsony labour market situation is likely to be most relevant for low skilled employment and remote areas and less so for mobile workers. This comment would also apply to involuntary unemployment. First Nations people may not migrate to find employment because of strong attachments to kin and country. So involuntary employment effects may be relevant for some remote rural areas and types of worker and not others (Laird & Mackie 2014, p. 95).

Both types of labour market WEBs will be uncommon and difficult for analysts to justify and estimate.

5.9 Conclusion

This chapter has considered each of the 3 types of WEBs that may apply to large transport projects in cities and 3 relatively unexplored WEB types that might be relevant for remote and regional road projects. Regarding the 3 WEBs applied to major city projects:

- Agglomeration WEBs (WB1) are not relevant.
- The labour market–taxation WEB (WB2) is relevant where the transport project generates additional employment. Estimation is straightforward using the methodology developed in Chapters 3 and 4, but any displacement effects should be deducted.
- The output changes in imperfectly competitive markets WEB (WB3) is relevant and straightforward to estimate.

The 3 other, less well-known WEBs are expected to be less common in practice and will be challenging for analysts to justify and estimate due to their greater information requirements. There is limited experience and guidance available for practitioners to draw on beyond Laird & Mackie (2014). This chapter has sought to clarify the issues and propose methodologies. However, they are yet to be applied and in doing so, lessons will be learned.

To keep WEBs in perspective, Laird & Mackie (2014, p 100) made the point that, on the basis of their case studies, the addition of WEBs to CBAs of road improvements in rural areas does not change the present value of benefits by large amounts, that is, it does not increase them by a factor of 2, 5 or 10. The additional benefits in their case studies increased the present value of benefits by a range of 1% to 64%. The variation in the range reinforces the point in ATAP (2023 T3) that the relationship between WEBs and conventional benefits cannot be approximated by percentage increase that can be applied across the board, but must be estimated on a case-by-case basis.

Following the guidance for estimating WEBs in UK DfT (2025a, b & c) and ATAP (2023 T3), there is a recommendation in Chapter 8 of the present report that project proponents provide a 'narrative' in their CBA reports explaining and justifying WEBs claimed.

6. Equity and justice

6.1 Introduction

Incorporating social benefits and WEBs into CBAs of remote and regional road projects is expected to have only a limited impact on CBA results, insufficient to support investment decisions that align with community expectations and government policy objectives. The worked examples in Appendix B illustrate this for social benefits. If road improvements in remote and regional areas are to be justified beyond economically efficient levels as indicated by CBA results, equity arguments need to be considered.

The theoretical basis of how CBA evaluates changes in social welfare was discussed in Chapter 2, starting with the Pareto criterion. Under the less restrictive Kaldor-Hicks criterion, a change is desirable (improves economic efficiency) if the gainers from the change could potentially compensate the losers out of their gains and still have something left over (a potential Pareto improvement). Gains and losses, measured in dollars are summed regardless of who the gainers and losers are, whether rich or poor. The difficulty with Kaldor-Hicks is that, as Sen (2017, p. 22) expressed it,

> An economy can be optimal in this [Pareto] sense, even when some people are rolling in luxury and others are near starvation as long as the starvers cannot be made better off cutting into the pleasures of the rich.

CBA, which tests whether the Kaldor-Hicks criterion holds, focusses exclusively on *changes* in the welfare of individuals without regard to the level of welfare they already have or will have after the project or policy has been implemented. To ignore the welfare status of the gainers and losers from a project or policy runs counter to widely accepted notions of morality, ethics or justice, and to the way in which political systems work.

This chapter reviews theories of equity and justice relevant to transport project appraisal and arrives at a recommended approach for investment in remote and regional roads. There is no generally accepted distinction between the terms 'equity' and 'justice' in the literature. Definitions of equity often use the word 'fair'. Some articles describe equity as an evaluation or state (that is, a situation is equitable or inequitable), and justice as the corrective action to address the equity concern (Walker et al. 2024, p. 7).

The discussion in this chapter has been greatly influenced by Martens' 2017 seminal book, *'Transport justice: designing fair transportation systems'*. Martens' main source of inspiration was Ronald Dworkin's theory of equality of resources, leading Martins to advocating adoption of the 'sufficientarian' theory as the guiding principle for equity in transport planning. Martens' work is limited to urban contexts, where there is a clear boundary within which to judge what level of accessibility is 'sufficient' and what improvements are feasible. A different approach is required for remote and regional roads where accessibility is low and the cost per person of improving accessibility is high.

The literature on equity and justice in transport policy tends to be qualitative. As this report aims to develop a rigorous quantitative approach to combining equity and efficiency in assessing road investments in remote and regional areas, we have interwoven the qualitative discussion of theories of justice with the mathematical presentation of social welfare functions (SWFs) used in economics. Over the last few decades, new ideas have appeared in literature on SWFs, in particular, Adler's writings advocating the 'prioritarian' approach, which leads to the application of equity weights to economic efficiency-based project benefits.

The early sections of the chapter introduce the broad philosophical ideas that underly the alternative approaches and the concept of SWFs. The question of extension beyond income and wealth to transport is addressed, following Martens' adoption of Walzer's idea of 'spheres of justice'. A number of theories of justice are reviewed — utilitarianism, Rawls' theory, Dworkin's theory, sufficientarianism and prioritarianism — to assess their relevance to remote and regional roads. Utilitarianism and the theories of Rawls and Dworkin are rejected. The recommended approach combines prioritarian and sufficientarian elements.

The literature on distributional equity is voluminous and often highly technical, straddling the disciplines of philosophy and economics. This report only gives a high-level overview of relevant theories. The aim is to find a defensible and practical approach to introducing equity considerations in investment decisions for roads in remote and regional areas.

6.2 Ethical bases for theories of justice

The most important normative ethical theories are consequentialism and deontology (Van Wee & Roesoer 2013, p. 747). CBA is related to utilitarianism which, in turn can be linked to consequentialism.

> Act consequentialism [distinguished from 'rule consequentialism'] is the claim that an act is morally right if and only if that act maximizes the good, that is, if and only if the total amount of good for all minus the total amount of bad for all is greater than this net amount for any incompatible act available to the agent on that occasion. (Stanford encyclopedia of philosophy, https://plato.stanford.edu/entries/consequentialism/)

In moral philosophy, the major alternative theory to consequentialism is deontology, from the Greek *δέον* (*deon*), 'obligation, duty'. While consequentialism is concerned with consequences, deontology focuses on the actions themselves, and specifically on duties. An action is judged right or wrong according to moral principles and rules. These principles include respect for each person, not causing harm, keeping promises, justice and fairness. The foremost deontological philosopher is Immanuel Kant. (Tseng, 2021, p. 6; Van Wee & Roesoer 2013, p. 747). Contractarianism and equalitarianism overlap with deontology.

For the contractarian, 'whether an act is right or wrong depends on whether it accords with or violates principles that would be the object of an agreement, contract, or choice made under certain conditions by members of a moral community' (Darwall 2008, p. 21 quoted in Van Wee & Roeseor 2013, p. 747). The theories of Rawls and Dworkin, discussed below, have a basis in social contract theory. Rational self-interested individuals would, if they had the choice, consent to the authority of government and to moral norms to secure the benefits of cooperation and social order. The social contract idea has a long history in philosophy associated the names such as Hobbes, Locke, Kant, and Rousseau.

Egalitarianism emphasises equality of rights for individuals, equal treatment of individuals, and reducing inequality throughout society. All the approaches in this chapter except utilitarianism are egalitarian in the broad sense of the term. However, utilitarianism treats all wellbeing as equally valuable no matter *whose* wellbeing it is (Chappell et al. 2024, p. 7. Italics in original). In the strict sense of the term, egalitarianism is concerned with *relative* wellbeing whereas sufficientarianism and prioritarianism (discussed below) are concerned with *absolute* wellbeing (Brown 2005, p. 201. Italics in original. Van Wees & Geurs, 2011, p. 356). From an egalitarian standpoint, a Pareto-type gain to an individual with above-average wellbeing is undesirable. According to Van Wee & Roeser (2013 p. 757), the main disadvantage of egalitarian theories is that it is difficult to determine what is fair where there are complex effects with winners and losers.

6.3 The social welfare function concept

In the economics discipline, much of the discussion of equity matters uses the SWF concept. The SWF aims to provide a way to compare the social desirability of alternative states of an economy in a way that is both rational and equitable (Russell & Wilkinson 1979, p. 401).

The SWF concept originated with Bergson (1938) and Samuelson (1947). A SWF is a rule or process for ranking or ordering social states that combines individual preferences to arrive at a ranking that is considered best for society as a whole. A social state is a list of all relevant economic variables including the amount of each commodity consumed by each individual and produced by each producer.

The Bergson and Samuelson SWF is an ordinal index of society's welfare. It is a function of the utilities of all individuals in the society, $W = W(U_1, U_2, U_3, \dots, U_n)$. These utilities depend on the quantities of goods consumed and work done by each individual. The Bergson-Samuelson SWF is based on value judgements involving interpersonal comparisons of utility in ordinal terms. The theory does not provide a way to make the required value judgements.

Arrow's Impossibility Theorem, first introduced in 1951, showed it to be impossible to construct a rational decision procedure to rank social states based only on ordinal preferences. Arrow's conditions for rationality are:

- transitivity: if *A* is preferred to *B*, and *B* is preferred to *C*, then *A* is preferred to *C*
- completeness: the ordering covers all possible social states
- non-dictatorship: the system does not depend on input from a single person
- the Pareto criterion: if at least one person prefers *A* to *B* and no-one prefers *B* to *A*, then *A* should be ranked more highly than *B*. In other words, the system does not ignore individual preferences
- independence of irrelevant alternatives: *A* being preferred to *B* should not change depending on whether *A* is preferred to *C*.

The theorem is a tightly constructed result in the sense that the result ceases to hold if any of the conditions are relaxed (Russell & Wilkinson 1979, p. 419). Much subsequent research has explored the consequences of weakening one or more of the conditions. The most influential set of ideas for SWFs arises from relaxing the assumption on ordinal preferences and allowing interpersonal comparisons of utility. Indeed, many authors hold that little progress is possible without allowing interpersonal comparisons of utility (Rietveld et al. 2016).

6.4 Accessibility as a sphere of justice

Much of the broader discussion of equity and justice concentrates on questions of human rights and liberties. The literature on equity from the economics discipline tends to focus on income, wealth and utility. Some authors in the field of justice or equity explicitly address the multi-dimensional nature of human wellbeing, recognising that equity in one dimension or 'domain of justice' does not necessarily imply equity in another. These other domains include access to education, healthcare, housing, rights and freedoms, and in the case of transport, accessibility and mobility.

Rawls, whose theory of justice is discussed below, identified 5 primary social goods' that all rational people would want — basic rights and liberties, freedom of movement and choice of occupation, powers and prerogatives of offices, income and wealth, and the social bases of self-respect (Martens 2017, pp 64-5). The freedom-of-movement primary good could be seen as relevant to transport. Van Wee & Geurs (2011, p. 356) argued that a basic level of access to some destinations could be labelled as an additional primary social good. The relevant destination categories include shops that sell food and other essential goods, schools and medical services.

Martens (2012 & 2017) built on Walzers' idea of 'spheres of justice' to argue that accessibility should be regarded as a separate domain of justice in its own right. In his 1983 book, *'Spheres of justice: a defence of pluralism and equality'*, Walzer developed a concept of 'distributive spheres' that are the prerogative of goods that have a distinct 'social meaning' that sets them apart from regular goods. All goods have social meanings. Goods can have different meanings in different societies, the same 'thing' being valued in one place and not in another. Regular goods, such as necklaces and cutlery, bought and sold in markets, are not deserving of consideration as a distributive sphere because their distribution is determined in markets via free exchange. Goods to which a society attaches a *distinct* social meaning, such as income, healthcare, education and housing, should be taken out to the sphere of free exchange into their own distributive sphere.

Walzer's theory provides no guidance as to the principle of distribution within spheres, only that it should be guided solely by internal reasons. Distribution within each distributive sphere should be (1) based on a principle other than free exchange, and (2) autonomous. Injustice will occur if the distribution of one good or set of goods becomes dominant and determines the distribution in other spheres (Martens 2017, p. 48). Typically, money and power are the goods claiming dominance, and the subject of much policy debate. Autonomy guarantees, what Walzer terms, 'complex equality', in which in inequalities within spheres may exist, but the inequalities will not necessarily sum up across the different goods or spheres (Martens 2012, p. 1037).

Martens (2012 & 2017) identified 2 distinct social meanings for the transport good — potential mobility and accessibility. Mobility refers to the ease with which a person can move through space. Accessibility refers to the ease with which destinations can be reached from a given location in space. Mobility implies freedom of movement in space including new experiences. However, it is not linked to valued goods and activities in specific locations. Accessibility captures the potential to participate in activities. Thus, Martens argues that accessibility rather than potential mobility best captures the social meaning of transport in current Western societies.

As a separate sphere of distributive justice, the level of accessibility of each group in society should be considered in relation to the levels of other groups. There is a substantial literature on transport-related social exclusion (defined in Section 3.1), which supports the idea that accessibility should be considered a sphere of justice. Poor accessibility can create a barrier to people obtaining a job, accessing health care, participating in education and maintaining contact with friends and family. Transport-related social exclusion can have a major impact on people's lives. (Martens et al. p. 4). The amount of accessibility can shape a person's life opportunities.

Having established that accessibility should be the unit of account for consideration of equity in the transport area, the next step is to review alternative theories of equity that might be applied.

6.5 Relevant theories of justice

Lewis et al. (2021) identified a number of theories of justice applicable to transport research and practice. Other authors have added more theories to the list (Van Wee 2012; Periera et al. 2017). This report only discusses a subset of these, found to be directly relevant to the question at hand. We have avoided reference to the concepts of 'horizontal equity and 'vertical equity' because, as Lewis et al. (2021, p. 10) point out, the terms are imprecise with different meanings given by different authors.

The egalitarian theory cannot be applied fully to the distribution of income because of the need to preserve incentives. Nor can it be applied to accessibility because 'space by its very nature is divided into centre and periphery' (Martens 2012, p. 1046). Inevitably, some people will live further away from valued activities than others. The policy question is how and to what extent should inequality be reduced.

All of the theories of equity discussed below except utilitarianism support greater equality. With the exception of utilitarianism, they are consistent with the Pigou–Dalton equity axiom. Simply stated, the axiom requires that, other things being equal, a SWF should prefer allocations that are more equal. In formal terms

- Let social state *v* be reached from *w* via a pure gap-diminishing transfer of wellbeing from a better-off person to a worse-off person, affecting no-one else. Then *v* is strictly preferred to *w* ($v \succ w$). By 'pure transfer,' is meant that the loss of wellbeing for the transferor equals the gain of wellbeing for the transferee. (Adler 2024, p. 5; https://plato.stanford.edu/entries/prioritarianism/)

All the approaches discussed below satisfy the axiom of separability, which means that the ranking of outcomes is not influenced by the utility levels of unaffected people. Separability has the practical advantage that the analyst can focus solely on determining the utilities of those whose wellbeing would be changed by a policy or project and not worry about how the policy or project would alter their position relative to the potentially vast number of unaffected people (Adler 2016, p. 267).

6.5.1 Utilitarianism

The philosophical literature covers a range of utilitarian theories of morality (see for example, Eggleston 2014). In the economic context, the sum-ranking form of utilitarianism is relevant.

A mathematical definition of the utilitarian SWF is

$$w \succcurlyeq v \text{ iff } \sum_i U_i(w_i) \geq \sum_i U_i(v_i)$$

where

- w_i and v_i are 2 vectors of outcomes under different social states, for example, income levels, for each individual *i* in society
- $w \succcurlyeq v$ means social state *w* is ranked as least as highly as social state *v*.

Utility is taken to be cardinal and can be objectively measured. Individual utilities are summed and the social state with the higher utility is preferred.

Utilitarianism posits that human wellbeing (utility) is the only intrinsic value and therefore at the core of justice concerns. It gives equal weight to everyone's welfare and interests (Periera et al. 2017, p. 172).

An important attribute of the utilitarian SWF that sets it apart is that it takes no account of base-case wellbeing, only the *change* in wellbeing under consideration. The utilitarian decision rule could be rewritten as

$$w \succcurlyeq v \text{ iff } \sum_i [U_i(w_i) - U_i(v_i)] \geq 0$$

which shows that the 2 social states are compared by summing the individual *differences* in utilities between the alternative states.

There are claims in the literature that utilitarianism is the basis of CBA (for example, Thomopoulos et al. 2009, p. 353; Van Wee & Roeser 2013, p. 744.). This is correct insofar as it refers to the way CBA sums monetary equivalents of changes in individual utilities, but is not strictly true. Seeking to maximise net benefits in monetary terms, as does CBA, only coincides with utilitarianism if utility weights are applied (Van Wee 2012, p. 4). As discussed above in Section 2.2, utility weights rescale monetary gains and losses to individuals to coincide with changes in utility.

6.5.2 Rawls and leximin

Rawls' theory of justice is seen as a radical critique of utilitarianism. Rawls considered that utilitarianism does not take seriously or respect the distinctive character of individuals and accepts as justified the sacrifice of individuals' interests or wellbeing for the good of society (Audard & Forsé 2022, p. 6).

Rawls (1971) (and Dworkin in the following section) justifies his theory on a social contract basis. Rawls posits a thought experiment in which unborn individuals are in 'the original position' needing to agree on the principles of social justice that will structure the society they will inhabit. Each person is rational and entirely self-interested. The agreement is made behind a 'veil of ignorance' that ensures no one can tailor the principles to their own advantage. No one knows the characteristics they will have in life, their gender, race, social class, tastes and preferences, or natural endowments such as levels of intelligence and physical strength. They are not even aware of the probabilities of having each attribute so decisions are not made based on calculations of expected pay-offs (Martens 2017, p. 65).

Rawls argues that people in this original position would use maximin reasoning, that is, maximise the minimum level of primary goods (defined in Section 6.4) they might find themselves having. Two principles of justice emerge. The first is equal basic liberties for all. The second is that social and economic inequalities must satisfy 2 conditions:

- They are to be attached to offices and positions open to all under conditions of fair equality of opportunity.
- They are to be to the greatest benefit of the least-advantaged members of society — the difference principle.

The difference principle allows those who are better endowed to gain more wealth and income only on the condition that their doing so also benefits their fellow citizens. The principle applies to income and wealth only, not to the other primary goods.

The leximin rule is less restrictive than Rawls' difference principle, allowing improvements to be accepted for individuals with intermediate levels of wellbeing. The leximin SWF prioritises the wellbeing of the least well-off individual by first maximising the utility of the worst-off individual, then maximising the utility of the second-worst-off individual, and so on, until all individuals are considered. In essence, the leximin rule is a lexicographic ordering of individuals' utilities, with the worst-off individual taking precedence. The difference principle, focussing exclusively on the worst off, considers only the first step in applying the leximin rule.

Martens (2017) explored possible ways in which accessibility could be incorporated into Rawls' framework, drawing on attempts to do so in the literature on equity in healthcare. None of the approaches were found to be satisfactory because they require making interpersonal comparisons of utility. Such comparisons are necessary when improvements to accessibility for the access-poor come at the expense of incomes to one or both of the income-rich and the income-poor. Accessibility improvements then have to be weighed against decreases in income and wealth. Such weighing falls outside the scope of Rawls' theory of justice. The difference principle requires only identification of the worst-off representative person, which only requires ordinal judgements of the relative position of individuals and comparisons to be undertaken on the basis of income or wealth (Martens 2017, p. 71). Taxing high-income people to fund improving access for people with the poorest access is only warranted under the difference principle where the improved access raises productivity resulting in additional income that can then be redistributed to the most disadvantaged people.

In contrast, interpersonal comparisons of utility are not a problem for SWFs. There is instead the question of 'leaky' transfers. A transfer is said to be leaky if the wellbeing of the transferor is reduced by more than the wellbeing of the transferee is increased. This contrasts with the 'pure transfer' defined in Section 6.2 in which there is no net loss of wellbeing.

Causes of leakage in transfers include economic efficiency costs (deadweight losses) from redistribution via the tax and welfare systems, and administration costs of running those systems. In the transport context, investment in infrastructure with benefits less than costs causes leakage of economic welfare because the gains to the beneficiaries are smaller than the loss to taxpayers.

The utilitarian SWF will not tolerate leaky transfers. The leximin SWF is 'absolutist' in the sense that any transfer from the better-off to the worse-off is considered to be an ethical improvement regardless of how large the loss to the better-off and how small the gain to the less well-off (Adler 2016 & 2022). Brown (2005, p. 207) gives the example of a choice between giving a chocolate to the worst-off person or alleviating pain for better-off people.

Because the difference principle and leximin SWF do not allow for trading off efficiency and equity, we consider them unsuitable as the basis for introducing equity into decision-making for remote and regional roads. This point is elaborated below in the context of sufficientarianism.

6.5.3 Dworkin's theory of equality of resources

Having rejected Rawls' difference principle for the distributive principle applied to transport accessibility, Martens (2017) found a starting point in Ronald Dworkin's theory of equality of resources.

Like Rawls, Dworkin (1983) based his principles on an original-position thought experiment. A group of people, having survived a shipwreck, are stranded on a desert island. The island has various resources (land, food, water) that need to be distributed among the survivors. Each survivor is given an equal number of clamshells (a fictional currency) to bid for the available resources. Survivors bid for the resources they value most. For example, someone who values a fertile piece of land might bid more clamshells on it than someone who prefers access to a fishing spot. After the auction, there is an 'envy test' whereby each survivor is asked whether they envy the bundle of any other survivor. If everyone prefers their own bundle over everyone else's, then the distribution can be considered fair. The auction leads to an efficient allocation of resources because it ensures that resources go to those who value them most. It is fair because everyone started out with the same number of clamshells.

Martins (2017, pp. 91-5) argues that allocation of land on the island would be fair. People with a strong preference for out-of-home activities and a dislike of travel would bid more clamshells for a piece of land with high accessibility, leaving fewer clamshells available to them to bid for other resources. Conversely, people who value accessibility less highly would bid for less central plots of land. This is consistent with the positive relationship in cities between land values and accessibility.

In the real world, abilities are unequally distributed. Dworkin continued his thought experiment to address situations where people have bad luck in the distribution of abilities. Dworkin distinguished between 'option luck' and 'brute luck'. Option luck occurs where people take deliberate gambles with their bundles of resources. If a person takes a gamble and loses, there is no case for compensation. Brute bad luck arises from unforeseen circumstances, such as being born with a disability. Each person is given the opportunity to spend some of their clamshells on insurance to compensate them in the event of brute bad luck. Persons can choose different levels of insurance coverage at different prices. In this way, brute luck is turned into option luck. If a person declined to purchase insurance and suffered an unforeseen disadvantage, this would be a gamble they have accepted and no compensation would be justified. An issue considered in Chapter 8 of this report is whether people living in remote and regional areas have made a voluntary choice or not. Where the choice is voluntary, it is questionable whether consequent social exclusion requires special consideration (Van Wee & Geurs 2011, p. 353).

Martens (2017, pp. 115-120) considers the case where the shipwreck survivors are assigned land at random locations on the island instead of purchasing land at the auction. The allocation of land then becomes a matter of brute luck. This is relevant to the real-life situation of people being born and raised in a particular location and being reluctant to leave. In Martens' scenario, people could purchase insurance against being assigned a plot of land with high access but unaffordable rents, or a plot of land with poor access. The insurance scheme is akin to governments levying taxes and spending the proceeds to fund measures to improve the accessibility of the access-poor.

In Dworkin's original position, with a population of N individuals to be randomly allocated to N positions in society, each individual has an equal probability, $1/N$, of finding themselves occupying any given position. Say the utility in each position i is u_i. The expected utility in the original position is then the average utility, $\sum u_i/N$. For an insurance scheme to be viable it has to increase expected utility, which requires total utility, $\sum u_i$, to increase.

Individuals purchasing insurance contribute to a pool of funds from which payouts are made to people suffering an adverse outcome. For insurance to be worthwhile for an individual, the *certain* loss of utility from paying into the pool has to be outweighed by the net gain in *expected* utility knowing that a payout will be received in the event of the bad outcome being insured against. A critical assumption in economic models of insurance is diminishing marginal utility from income. The assumption guarantees that sum total loss of utility to the purchasers of insurance from buying the insurance, is less than the sum total gain in utility to the subset of purchasers who experience the adverse outcome being insured against. The reason is that the latter, who receive the insurance payout, have a much higher-than-average marginal utility of income. Dworkin's insurance scheme is a form of utilitarianism because it seeks to maximise average utility by redistributing from a majority of people with low marginal utilities of income to a minority of people with high marginal utilities. A number of authors have made this point though Dworkin himself did not recognise it (Stein 2001; Fleurbeay 2002). They have also noted that redistribution via insurance fails the envy test (Otsuka 2002, p. 47).

In Martens' discussion, the insurance payout is used to improve access, not to pay financial compensation as presumed by Dworkin. The utility gain from the accessibility improvement to the access-poor therefore has to outweigh the loss of utility to all individuals from contributing to the pool. A leaky transfer, using utility as the welfare measure, would not be accepted in a social contract for insurance made in Dworkin's original position because expected utility (equal to average utility) would be lowered. It is shown in Chapter 8 that, using our logsum utility measure and with income level not related to accessibility, the Dworkin–Marten outcome is identical to that for maximising economic efficiency.[30]

Based on his accessibility version of Dworkin's insurance thought experiment, Martins (2017, p. 126) concludes that people having accessibility below some threshold level of sufficiency is a case of injustice that

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[30] Martens (2006, pp. 11-12) conjectured that there may be diminishing marginal utility from accessibility gains. However, this would only be relevant if the access-rich accepted a reduction in accessibility to fund increases in accessibility to the access-poor. If utility is the log of our CI (the logsum), there is diminishing marginal utility with respect to population in destination zones but not with respect to travel times. Road improvements only improve travel times, not destination populations.

the community as a whole should contribute to address. This leads Martens to the 'sufficientarian' theory of equity, addressed in the next section. Martens (2017) did not recognise the utilitarian nature of Dworkin's scheme, or that the scheme does not support economically inefficient spending to improve access. While we disagree with Martens linking of sufficientarianism to Dworkin's theory, sufficientarianism is a theory of distributive justice in its own right.

6.5.4 **Sufficientarianism**

Sufficientarianism (or sufficientism) is a theory of distributive justice centered around the idea that everyone should have *enough* of some relevant form of advantage.

> With respect to the distribution of economic assets, what is important from the point of view of morality is not that everyone should have the same but that each should have enough. (Frankfurt 1987, p. 21)

Roemer (2004) advises interpreting the principle as maximising the number of people who have enough. This corresponds to 'weak sufficientarianism'. In the case of 'strong sufficientarianism', people whose level of wellbeing is below the threshold defined as 'enough', would be prioritised in ascending order starting with the least well-off (Van Wee & Geurs 2011, p. 356; Lucas et al. 2016, p. 477).

Martens (2017, p. 214) defines a fair transportation system as one 'that provides a sufficient level of accessibility to all under most circumstances'. He suggests 2 alternative approaches to determining 'sufficient' accessibility,

- data collection and analysis to develop a detailed understanding of the empirical relationship between accessibility levels and the quantity and quality of activity participation
- ranking population groups in terms of experienced accessibility levels to assist decision-makers to set a sufficiency standard in a pragmatic way.

Both approaches need to be accompanied by 'democratic deliberation'. Martens (2017, pp. 141 and 173) allows for a 'zone of disagreement' between the ranges of clearly insufficient and clearly sufficient accessibility, where people having different views about equity are unable to agree on a particular threshold. Further democratic engagement would be needed to manage situations where the threshold in the range of disagreement was critical to decision-making.

The transport system is then split into 2 domains of justice (Vanoutrive and Cooper 2019, p. 114). The range of accessibility below the threshold belongs in the 'domain of justice', referring to Walzer's framework. For people below the threshold, improvements are required, financed by a fair scheme of taxation. The range of accessibility above the threshold belongs in the 'domain of free exchange'. Improvements in accessibility above the threshold are optional and only allowed if they do not increase the number of people falling below the threshold (Martens 2017, p 144).

Application of sufficientarianism to determine equitable access in the case of remote and regional roads in Australia would be problematic. Martens' work is entirely concerned with urban environments where there are well-defined city boundaries. Within the boundaries, the people with the poorest accessibility can be identified and their accessibility improved for a cost that the community may reasonably be able to afford. Moving beyond city boundaries into regional and further into remote areas, accessibility progressively declines with population density. Costs of improving accessibility through spending on infrastructure and subsidising public transport mount due to the distances involved. Costs per person rise due to small numbers of transport users. Investing in roads beyond economically efficient levels is a case of leaky transfer, and the size of the leakage required to meet a given sufficiency standard rises with remoteness. As discussed in Section 1.2 above, the cost would be prohibitive unless the sufficiency threshold was set so low as to be irrelevant for much of Australia.

6.5.5 **Prioritarianism**

Prioritarianism was introduced to philosophy by Derek Parfit in a lecture given in 1991. It gives priority to individuals at lower wellbeing levels (Adler 2022).

> It holds that improvements in someone's life (gains in wellbeing) are morally more valuable, the worse off the person would otherwise be. (Arneson 2022)

The idea has been applied in a variety of policy domains including taxation, healthcare, fatality risk reduction, climate change, education and the Covid-19 pandemic (Adler 2022). Brown (2005, pp. 206-8) distinguishes between 'absolute prioritarianism,' which is identical with the leximin SWF, and 'weighted prioritarianism', whereby benefitting people matters more, the worse-off those people are, and the greater the benefits in question. Welfare changes are weighted using a mathematical relationship that uprates gains to the less-well-off in relation to gains to the well-off.

The weighted prioritarian SWF is

$$w \succcurlyeq v \text{ iff } \sum_i g[U_i(w_i)] \geq \sum_i g[U_i(v_i)]$$

where $g(\cdot)$ is a strictly increasing, concave and continuous transformation function and the variables are as defined in Section 6.5.1.

The function is illustrated in Figure 6.1, where w_L is the wellbeing level of a worse-off person and w_H, the wellbeing level of a well-off person. The same increment in welfare, Δw, applied to both individuals, produces a larger increase in transformed wellbeing for the worse-off person than for the well-off person. The more concave (curved) the transformation function, the greater the tendency towards equalitarianism (Adler 2024).

Adler (2016) recommends using an isoelastic transformation function, the form of which was given in Section 2.2.2 on utility weighting. The weights are derived from the slope or first derivative of the function, $g'[U_i(v_i)]$, and so decline as wellbeing increases.

Provided the change in utility levels from the base-case wellbeing outcomes, the v_i's, to the project-case wellbeing outcomes, the w_i's, are not large (so the slope of the curve does not change much between the base case and the project case), the decision rule, using weights, could be written as

$$w \succcurlyeq v \text{ iff } \sum_i g'[U_i(v_i)] \cdot [U_i(w_i) - U_i(v_i)] \geq 0$$

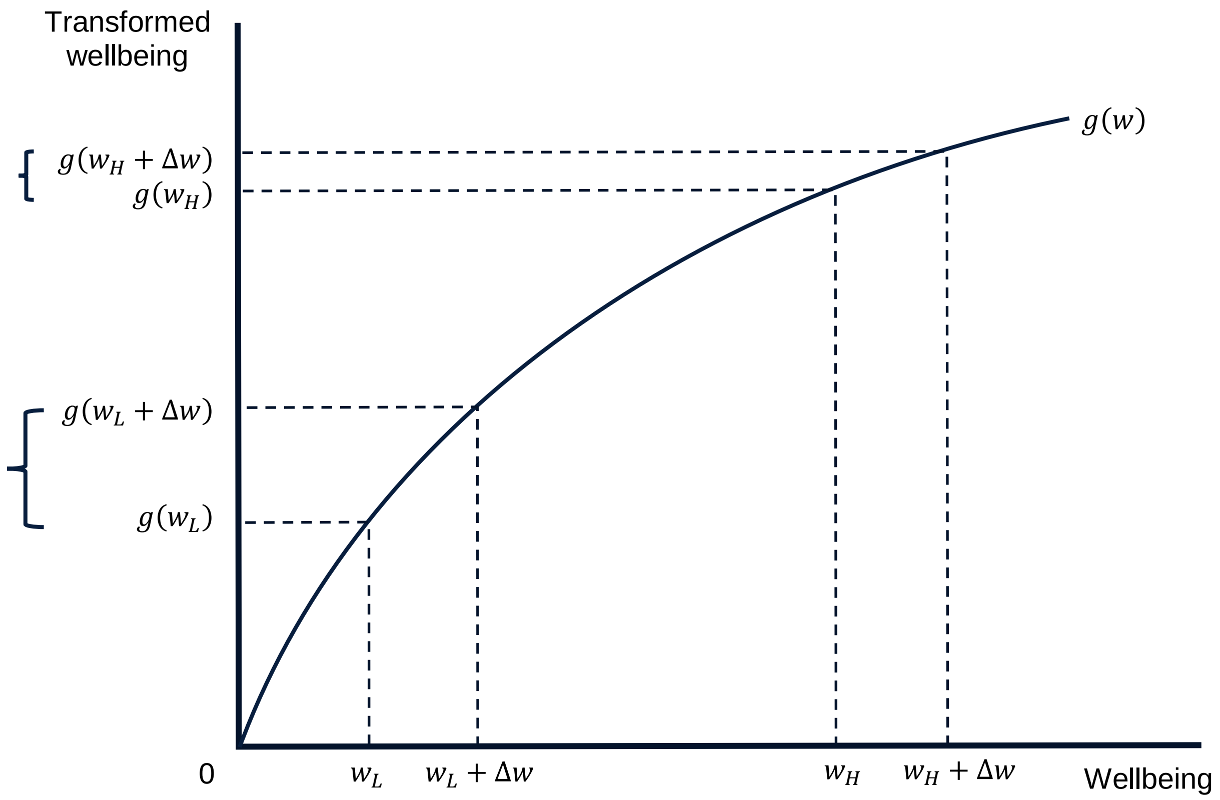
The weights would be determined by the base-case level utility levels of individuals.

Application of a prioritarian SWF in a CBA requires both conversion of monetary impacts to units of utility (utility weighting), then transformation to social welfare units (equity weighting). Utility weighting corrects for diminishing marginal utility but does not address distributional equity (Acland and Greenberg 2023a, p. 70). Utility weights reflect consumer preferences while equity weights reflect the moral or ethical judgements of decision-makers. The full weight applied to a benefit expressed in monetary terms is the product of the utility weight and the equity weight.

The prioritarian approach supports transfers from the rich to the poor with some leakage, but only up to a point. The prioritarian SWF could therefore be seen as a compromise between the utilitarian and leximin SWFs.

An example from the health economics literature of how the base-case status of individuals affects rankings under prioritarianism is the 'fair innings' argument. Combining a prioritarian SWF with a lifetime utility model, the conclusion is reached that, other things being equal (income and risk profiles of individuals), an additional year of life for a younger individual is worth more than an additional year of life of the same quality for an older individual because the younger person has enjoyed fewer years of utility (Williams 1997; Adler et al. 2021; Adler 2024). The fair innings argument is not without controversy (for example, Rivlin 2000) and the 'other things being equal' assumption is critical.

Figure 6.1 Prioritarian transformation function



Source: Adler (2024, p 6).

Acland and Greenberg (2023a) criticised equity weighting for conflating information about efficiency and equity impacts. The same net benefit number could be achieved by a policy that greatly benefits wealthy people while imposing significant costs on the poor, as by a policy that narrows the gap between the rich and poor while lowering aggregate welfare. This would be correct if the benefits to the wealthy were sufficiently large. However, policy and project decisions are never made on the basis of a single number. The unweighted CBA results and other information provided to decision-makers would ensure they fully understood both the efficiency and distributional impacts.

6.5.6 Combined prioritarian–sufficientarian approach

The strong sufficientarianism approach mentioned above prioritises individuals below the sufficiency threshold starting with the worst off and continuing in ascending order. Brown (2005) put forward approaches that apply a transformation function to both wellbeing below and wellbeing above a threshold. Social states are ranked first by comparing weighted wellbeing summed over all individuals below the threshold. Social states that are equal by this criterion, can be further ranked on the basis of the weighted wellbeing summed over individuals above the threshold. In the notation previously used, total weighted wellbeing below the threshold is

$$w \succcurlyeq v \text{ iff } \sum_i min\{g[U_i(w_i)], g[U_i(\alpha)]\} \geq \sum_i min\{g[U_i(v_i)], g[U_i(\alpha)]\}$$

where α is the threshold. Taking the minimum causes the threshold wellbeing score assigned to each person above the threshold to equal $g[U_i(\alpha)]$. Thus, an improvement in the wellbeing of a person above the threshold does not add to social welfare.

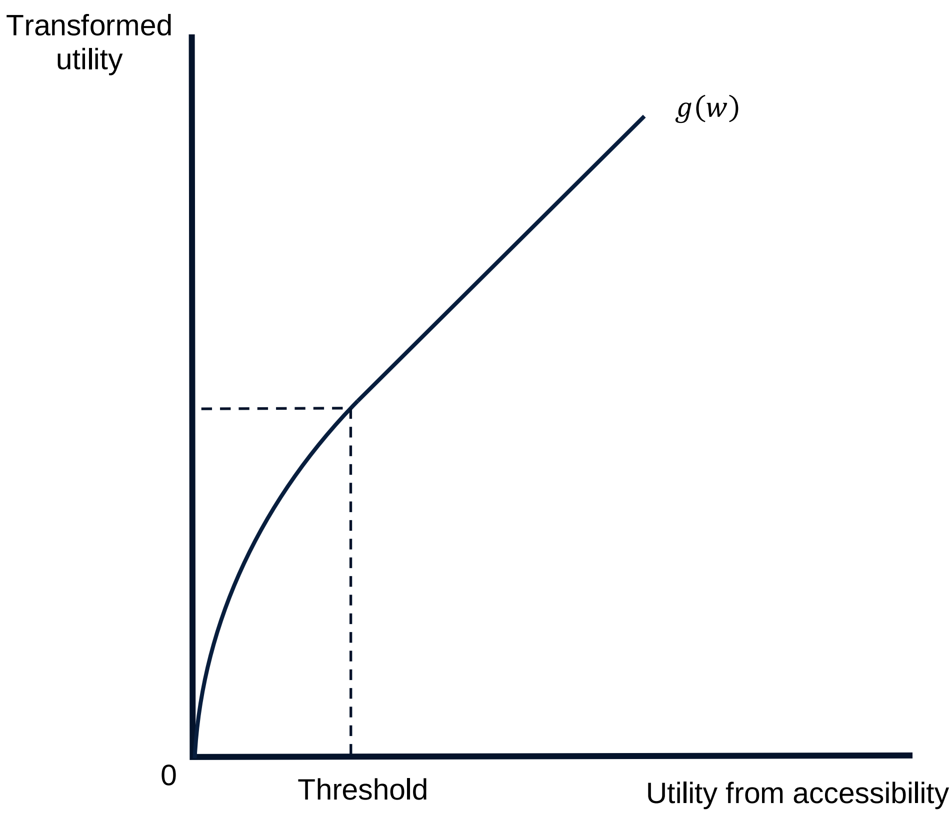
Social states that have equal weighted below-threshold total wellbeing, can be further ranked based on the summed total weighted wellbeing for individuals above the threshold using a different transformation function.

Adler & Holtug (2019) termed Brown's approach 'prioritarianism with a lexical threshold' and noted that the idea 'has been little discussed in the philosophical literature'.

6.6 Recommended approach for remote and regional roads

For remote and regional roads this report recommends a modified form of what Brown called 'absolute sufficientism'. The concave transformation function below the threshold and linear transformation function above proposed by Brown (2005) are retained, but without absolute priority given to the welfare of those below the threshold. The transformation function, shown in Figure 6.2, would be applied in the same way as the prioritarian transformation function.

Figure 6.2 Sufficientarian – prioritarian transformation function



The isoelastic function introduced in Section 2.2 could be used as the transformation function below the threshold. The transformation would be applied to the *utility* from accessibility, *U(A)*, which is the log of the CI (the logsum). The isoelastic function is multiplied by a scaling factor *U(T)* that makes the weight equal one at the threshold accessibility level, *T*.

Above the threshold, the curve is a straight line with a slope of one. The curve is continuous at the threshold, where $U(A) = U(T)$, because both the isoelastic and linear parts of the curve have the same value.

The transformation function is

$$g(A) = \begin{cases} \dfrac{U(T)^{\eta}\, U(A)^{1-\eta} - 1}{1-\eta}, & A < T \\ \dfrac{\eta\, U(T) - 1}{1-\eta} + U(A)\,, & A \geq T \end{cases}$$

for *η ≠ 1*

$$g(A) = \begin{cases} U(T)\, ln\, U(A), & A < T \\ U(T)\, [ln\, U(T) - 1] + U(A), & A \geq T \end{cases}$$

for *η = 1*.

The weights are given by the first derivative of the function with respect to *U(A)*.

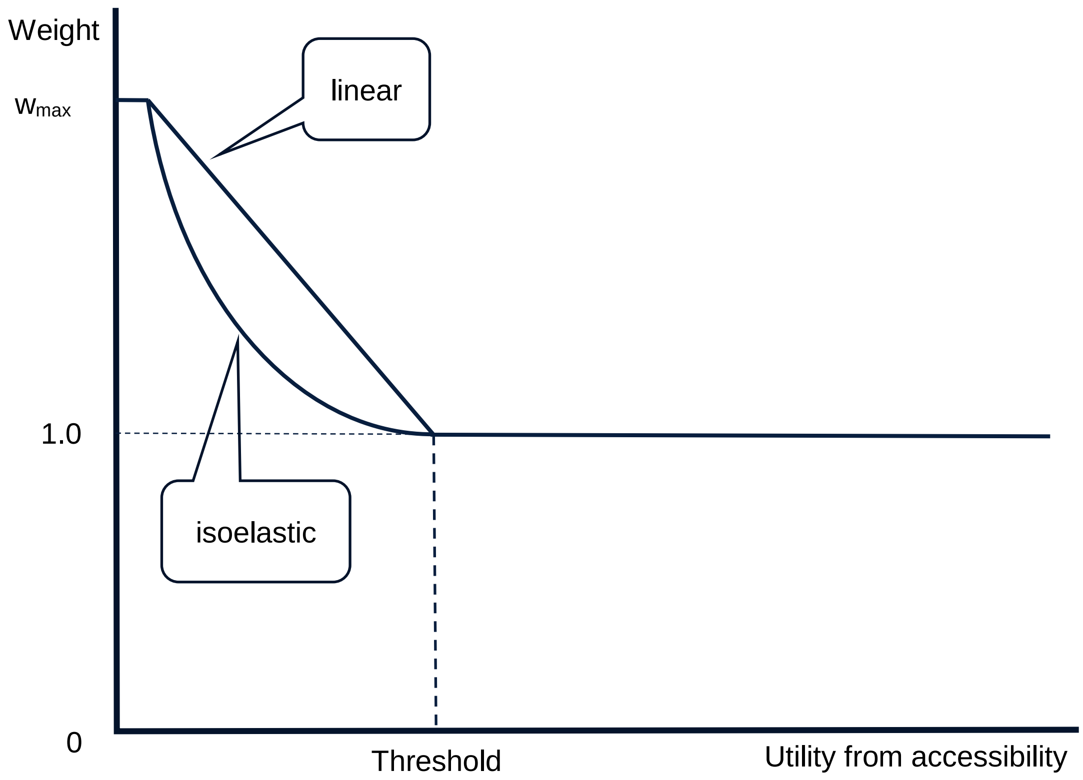
$$g'[U(A)] = \begin{cases} \left(\dfrac{U(T)}{U(A)}\right)^{\eta}, & A < T \\ 1, & A \geq T \end{cases}$$

The first derivative is the same for both *η ≠ 1* and *η = 1*. The weighting function can be written as

$$w[U(A)] = max\left[\left(\frac{U(T)}{U(A)}\right)^{\eta}, 1\right]$$

Figure 6.3 illustrates the isoelastic weighting function as well as the alternative linear weighting function put forward in Chapter 7.

Figure 6.3 Sufficientarian – prioritarian weighting functions



The isoelastic and linear weighting functions shown in Figure 6.3 give weights of one for benefits accruing to people with accessibility levels above the threshold. Thus, no weighting of benefits occurs for CBAs of roads in areas of acceptable accessibility. The utility level at the threshold plays the same role as does the median income level in utility weighting in that it fixes the point where the weight is one

Moving leftward from the threshold, the weights increase gradually, so equity is given an increasingly greater weight over economic efficiency, the poorer the level of accessibility.

In the case of the isoelastic function, the first derivative of both parts of the transformation curve is one at the threshold, where $U(A) = U(T)$, so there is a smooth transition in the weights in the region of the threshold.

Since utility is the log of the accessibility index, utility will become zero when the CI falls to one, and negative for accessibility below one. As the scale on which utility is measured is arbitrary (only relative utilities matter), this is not a problem for the utility measure. However, isoelastic weights will approach infinity as accessibility approaches one from above. In Figure 6.3, an upper limit has been set for the weights at w_{max}.

6.7 Conclusion

This chapter has taken the reader on a tour of concepts of economic equity with the aim of finding a suitable framework to apply to roads in remote and regional areas. It has drawn on literature from the philosophy, economics and transport planning disciplines.

Much of the philosophical and economic discussion of equity issues concerns the distribution of income and wealth. Walzer's idea of 'spheres of justice' argues for separate treatment of equity for different areas of life such education, healthcare, housing, rights, freedoms, income and wealth. In the transport literature, Martens and Van Wees have proposed adding accessibility to the list of spheres of justice.

A number of theories of justice have been examined:

- Utilitarianism, maximising the sum of utilities across all members of society, takes no account of equity. It is not consistent with the Pigou–Dalton equity axiom that gives preference to more equal allocations of wellbeing.
- Rawls' difference principle is attractive because it is highly egalitarian and has a social contract justification, rather than relying solely on moral judgement. Absolute priority is given to the least well-off. It is considered unsuitable for accessibility in remote and regional areas because it permits extremely leaky transfers that would benefit the least well-off by small amounts but come at a great cost to the rest of society. In remote areas, costs of upgrading long lengths of roads can be prohibitively high with small benefits due to low populations.
- Dworkin's hypothetical insurance scheme also has a social contract justification, but on closer examination, is found to reduce to utilitarianism. It will not tolerate leaky transfers when evaluated in utility terms.
- Sufficientarianism seeks to ensure everyone has 'enough'. It has a moral or ethical rationale but Martens, incorrectly in our view, claims it to follow from Dworkin's hypothetical insurance scheme. Martens contends for sufficientarianism in transport planning for urban areas. However, outside the boundary of a metropolitan area, in areas of low population densities, unless the sufficiency threshold is set at a very low level, the transfers needed to provide sufficient access can be unacceptably leaky — the same objection as for Rawls' theory.
- Prioritarianism holds that it is more valuable to improve the wellbeing of a worse off person than a better-off person. It weights welfare gains to individuals according to a mathematical function that gives greater weight to a benefit received as wellbeing diminishes. It allows leaky transfers, but only to a controlled extent.

Our recommended approach combines prioritarianism and sufficientarianism. It accords a weight of one to all accessibility levels above a threshold level, then progressively increases the weight as accessibility falls below the threshold up to a maximum level for the weight. This approach is developed further in the next chapter.

7. Equity weighting

7.1 Introduction

The previous chapter concluded by recommending the application of equity weights above one to benefits from accessibility improvements for people residing in locations with CIs below a threshold level. The weights vary inversely with CIs over a range between one and a set maximum. This chapter addresses the implications of equity weighting and how the weights would be applied by developing a model in which income is taxed to fund road spending to improve accessibility.

The utility of a representative individual in each zone depends on their income and accessibility, measured by the CI. All residents pay a uniform tax out of their income to fund roads in each region. Average income is the same in all regions, but CIs vary.

A simple version of the model is first introduced with each zone having just one origin–destination pair in its CI. By maximising total utility first and then expected utility, it is demonstrated that under the assumptions of the model, the utilitarian and Dworkin insurance approaches to equity described in Section 6.5 above, both lead to the most economically efficient outcome as derived in Section 2.3, with the MBCR equal to one. Insertion of a prioritarian weighting function into the equation is needed to make investment deviate from economically efficient levels in favour of zones with lower CIs. The weights give a decision-maker scope to determine how much to tax income to fund road spending, and to adjust the relative priorities given to the access-rich and the access-poor.

A detailed version of the model in which each road segment is used by traffic from multiple origins and destinations is developed to show how to apply the recommended equity weighting approach from Chapter 6. In a CBA of a road improvement on a given road segment, the practitioner has to multiply the benefits for car traffic originating from each SA1 by the relevant equity weight for that SA1.

Finally, weighting functions are derived from our CI values for SA1s outside major cities with plausible parameter values to understand how use of the different parameter values, CIs and functional forms affects the weights. Two functional forms are discussed — isoelastic and linear. The implications of using the 3 different CIs calibrated in Chapter 3 and parameter values in the functions are investigated.

In our model, as proposed in Section 6.6, the equity weights are a function of accessibility, not income. The marginal utility of income is taken to be constant across all zones. Supporting arguments for separate treatment of equity of accessibility and equity of income distribution are as follows:

- The idea of domains or spheres of justice was introduced in Chapter 6 along with Martens' argument for accessibility to be considered as a sphere of justice. Walzer considered that equity in each sphere of justice should be considered in isolation from the other spheres.
- It was found in Chapter 3 that there was practically no correlation between median personal income levels in SA1s and the CI. Average incomes are lower in the most remote zones, but equity weights based on accessibility will favour those zones regardless of income.
- As there would be a spread of incomes within each SA1, weights linked to median income in each SA1 would not necessarily divert road spending to assist the least well-off in income terms. Policy instruments other than road spending can better target low-income people.
- Use of equity values of travel time savings in CBAs removes the effect of differences in the marginal utilities of income on the value of time but it is equivalent to assuming uniform marginal utility across all income groups. The recent WTP survey reported in ATAP (2024) found no relationship between income and WTP to save time.

Basing the equity weights solely on accessibility, regardless of income, differentiates our model from the model in Nahmias-Biran & Shiftan (2016). They proposed a distributional weighting system for assessing transport projects in urban areas. In their system, the weights for differences in accessibility were dependent upon income and accessibility being correlated. For benefits accruing to people in a zone with poor accessibility to have a higher weight, they also need to have low incomes, and conversely. In their two-zone numerical example, the 'poor' zone with low accessibility would only receive a higher weight to the extent that average income in the zone was lower than average income in the 'rich zone' with high accessibility. Furthermore, their weights were derived from a relationship between a 'subjective wellbeing' measure and income, not a moral judgement. As such, their weights were, in fact, 'utility weights' as defined in Chapter 2, not equity weights based on moral judgements. The relative sizes of their weights are limited to variations in the marginal utility of income. By omitting differences in income altogether, our system does not rely on a correlation between income and accessibility.

7.2 Simple illustrative versions of the model

This section presents a simple version of our model for introducing equity into assessment of improvements to remote and regional roads in which each origin zone has just one destination zone and one road.

7.2.1 Model setup

The indirect utility function for a representative person in zone *i* is

$$U_i = U_i(y, \boldsymbol{p}, q_i, A_i)$$

where:

- *y* is income. There is no subscript because average income is assumed to be the same for all zones.
- ***p*** is a vector of prices of all goods. Because the prices of all goods are held constant, ***p*** will not be shown in the utility function from here on.
- q_i is the number of one-way trips per annum made by the representative individual in zone *i* equal to twice the number of round trips. This is a constant for each zone, typical of regular commuting trips. Although, the social benefits in Chapter 5 are based on induced travel, in the model of this chapter, induced trips are assumed to be so small in relation to existing trips that they can be ignored.
- A_i is the accessibility measure or CI for zone *i* as defined in Chapter 3. The CI does not include the money costs of travel, which are assumed to be small in relation to the time cost. It is therefore a quality variable in the utility function.

From random utility theory, discussed in Chapter 3, the log of the CI (the logsum) is the utility associated with accessibility. We partition a person's total utility into 2 parts assumed to be additive — the utility from spending their income, equal to $U(y)$, and the utility they gain from travel, equal to $q_i \, ln \, A_i$.[31] The utility from travel is proportional to the number of trips, q_i. Thus a person making 4 round trips a week experiences twice the utility from travel as a person who makes 2 round trips a week, on top of the utility they gain from their income.[32] The utility function becomes

$$U_i = U(y) + q_i \, ln \, A_i$$

From Chapter 3, the expected value of the maximum utility from accessibility or logsum is $ln \sum_j e^{\lambda \, t_{ij}} P_j^{\mu}$. With just one road and one destination, the logsum formula reduces to $U = \lambda \, t_{ij} + \mu \, ln(P_j)$. The *j* subscript can then be omitted. The utility function for the representative individual in zone *i* becomes

$$U_i = U(y) + q_i[\lambda \, t_i + \mu \, ln(P_i)]$$

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31 The technical term for this assumption is 'additive separability' (Brown & Deaton, 1972, p. 1166). In this case, it implies that the marginal utility of income is independent of the amount of accessibility the consumer has, and conversely, the marginal utility of accessibility is independent of the amount of income the consumer has.

32 There is literature on consumer choice models in which utility is a function for goods consumed and time spent on activities such as travel, work and leisure. Utility is maximised subject to both budget and time constraints. For a survey see Jara-Díaz 2007. Our model assumes hours worked are fixed, time savings due to improved accessibility are used for leisure, and there is no linkage between consumption of goods and leisure time.

where t_i and P_i are respectively the travel time and population for the single destination zone for zone *i*.

In Section 2.3, travel time as a function of spending on a road, was modelled as a continuous, decreasing, convex function, *t(x)*, illustrated in Figure 2.3. The annualised amount of spending on the road for each zone is x_i. The total annual cost of road spending across all zones is $\sum_i x_i$. This amount is deducted from the income of each individual in society in equal shares to pay for the roads. The whole population is *Z* with z_i living in each zone *i*. Thus $Z = \sum_i z_i$.

The utility for the representative individual in zone *i* is

$$U_i = U\left(y - \frac{\sum x_i}{Z}\right) + q_i[\lambda\, t(x_i) + \mu\, ln\, P_i]$$

7.2.2 Utilitarian social welfare function

The utilitarian SWF is obtained by summing utility over all *Z* individuals in all zones.

$$\sum U_i = Z \cdot U\left(y - \frac{\sum x_i}{Z}\right) + \sum z_i q_i[\lambda\, t(x_i) + \mu\, ln\, P_i]$$

To find the welfare-maximising level of spending for each road, x_i

$$\frac{\partial \sum U_i}{\partial x_i} = Z \cdot \frac{dU(y)}{dy}\left(-\frac{1}{Z}\right) + z_i q_i\, \lambda \frac{dt}{dx_i} = 0\ \forall i$$

Substituting in $MU_y = \frac{dU(y)}{dy}$ and rearranging

$$z_i q_i\, \lambda \frac{dt}{dx_i} = MU_y$$

Dividing both sides by MU_y,

$$z_i q_i\, \frac{\lambda}{MU_y}\frac{dt}{dx_i} = 1$$

Since $\frac{-\lambda}{MU_y} = v$ is the value of travel time savings (see Section 2.2), this result can be rewritten as

$$-z_i\, q_i\, v\, \frac{dt}{dx_i} = 1 = MBCR$$

which implies that investment in each road should occur up to the point where the MBCR is one. The MBCR concept was introduced in Section 2.3. It is the benefit from spending an additional dollar per annum on the road. The benefit is given by

- the number of people resident in zone *i*, z_i, multiplied by
- the number of one-way trips by each person resident in zone *i*, q_i, multiplied by
- the value of travel time savings, *v*, multiplied by
- the time saving per vehicle for a one-way trip on the road that results from spending an additional dollar on the road, $\frac{dt}{dx_i}$. This is negative because additional spending on the road *saves* time. The negative sign for $\frac{dt}{dx_i}$ cancels out the negative sign in the optimum investment rule.

The investment rule just derived is the same as that derived in Section 2.3 for economically efficient road investment. Hence, with marginal utility of income being the same for all zones, the utilitarian and economically efficient optimal investment rules are identical.

This conclusion relies solely on the marginal utility of income being the same for the representative person in each zone. Non-linearity of utility as a function of travel time would make no difference. The value of travel time savings has been found to increase with trip duration for longer inter-urban journeys, particularly for business travel (Wardman et al. 2016, p. 98). However, as long as the correct value of travel time savings is used for each zone depending on the distance travelled, the maximum utility and maximum economic efficiency investment rules would still be the same.

7.2.3 Dworkin insurance approach

It is now shown that the Dworkin insurance approach produces the same result as the utilitarian approach. Members of society are placed in an original position, without knowing which zone they will live in, and are asked to agree on an investment rule for road infrastructure. Unlike Rawls' original position, they know the probabilities for accessibility. The probability they will live in zone *i* is the proportion of the total population residing in that zone, z_i/Z. The total costs of all roads are divided equally among members of society as in the previous utilitarian model. Since the requirement for each person to pay $\sum x_i/Z$ out of their income is certain and is the same for residents of all zones, utility from income is not multiplied by the probability of living in a particular zone.

The expected utility for the representative individual in zone *i* is

$$E(U_i) = U\left(y - \frac{\sum x_i}{Z}\right) + \sum \frac{z_i}{Z} q_i [\lambda\, t(x_i) + \mu\, ln\, P_i]$$

$$\frac{\partial E(U_i)}{\partial x_i} = \frac{dU(y)}{dy}\left(-\frac{1}{Z}\right) + \frac{z_i}{Z} q_i\, \lambda \frac{dt}{dx_i} = 0\ \forall i$$

Multiplying through by *Z* results in the same investment condition as obtained for the utilitarian approach.

$$-\frac{dU(y)}{dy} + z_i q_i\, \lambda \frac{dt}{dx_i} = 0\ \forall i$$

7.2.4 Prioritarian SWF

The next model is the utilitarian model with a concave prioritarian transformation function, $g(\cdot)$, as described in Section 6.6, applied to utility from accessibility. Priority-adjusted utility for the representative individual in zone *i* is

$$U_i^* = U\left(y - \frac{\sum x_i}{Z}\right) + q_i\, g[\lambda\, t(x_i) + \mu\, ln\, P_i]$$

Total weighted utility, U^*, is

$$\sum U_i^* = Z \cdot U\left(y - \frac{\sum x_i}{Z}\right) + \sum z_i q_i\, g[\lambda\, t(x_i) + \mu\, ln\, P_i]$$

Partially differentiating with respect to x_i, and recalling that utility from accessibility is $U(A_i) = \lambda\, t(x_i) + \mu\, ln(P_i)$,

$$\frac{\partial \sum U_i^*}{\partial x_i} = -\frac{dU(y)}{dy} + z_i q_i \frac{dg[U(A_i)]}{dU(A_i)}\, \lambda \frac{dt}{dx_i} = 0\ \forall i$$

$$\frac{dg[U(A_i)]}{dU(A_i)} \cdot z_i q_i\, \lambda \frac{dt}{dx_i} = MU_y$$

$$-g'[U(A_i)] \cdot z_i\, q_i\, v \frac{dt}{dx_i} = 1$$

$$g'[U(A_i)] \cdot MBCR = 1$$

Project benefits would be weighted by $g'[U(A_i)]$ which varies inversely with accessibility, giving greater weight to zones with lower accessibility. Alternatively, cut-off BCRs for individual zones could be specified that vary inversely with accessibility calculated as follows:

$$MBCR_i = \frac{1}{g'[U(A_i)]}$$

For example, for a zone with an equity weight of 1.5, investments could be assessed either by multiplying benefits by a factor of 1.5, or by investing up to the point where the MBCR equals two-thirds.

The level of *U(A)* at which the weight is set to equal one plays an important role in the model. It determines the standards of roads provided at different accessibility levels, relative to the economically efficient standards. It also determines the total funding required for roads in the network, and hence the tax level.

- To illustrate the relationship between the weights and the tax, if all roads from all zones had a weight of one, the model would be identical to the utilitarian model in Section 7.2.2 with all roads provided at the most economically efficient standards. A uniform weight, *w*, below one applied to all roads would lead to over-investment in all roads up to an MBCR of *1/w* and the extra spending on roads would require a higher tax rate. Conversely, a uniform weight above one would lead to under-investment in all roads and a lower tax rate. Thus, the overall level of the weights alters the balance between marginal utility of income and marginal utility from accessibility, affecting the required total tax take.
- The weighting function could be normalised to equal one for the population-weighted average zone so that the balance between taxing and spending on roads was not affected. Total spending would remain the same and MU_y would be unchanged from the level without weights. Road spending would be shifted from zones with high accessibility (weight below one, cut-off BCR above one) to zones with poor accessibility (weight above one, cut-off BCR below one). The over-investment in poor accessibility zones would therefore be financed by under-investment in zones with good accessibility, as suggested by Figure 1.1 in Chapter 1.
- If the accessibility level with a weight of one was set at the top of the range of accessibility levels, all the weights would be greater or equal to one, increasing progressively as accessibility falls. The MBCRs would be less than or equal to one for all zones, rising with accessibility. The extensive over-investment in the road system would be funded entirely from higher taxation.
- If the accessibility level with a weight of one was set at the bottom top of the range of accessibility levels, all the weights would be less than or equal to one, falling as accessibility rises. The MBCRs would be greater than or equal to one, rising with accessibility. The savings in funds from the extensive under-investment in the road system would be returned to taxpayers via lower taxation.

The combined prioritarian–sufficientarian system recommended in this report sets the weights to one above a threshold accessibility level, and progressively increases the weights as accessibility falls below the threshold. Investment in roads above the threshold does not change much.[33] The over-investment in roads below the threshold would be funded by higher taxes.

7.3 Full model with equity weights

This section develops the full model in which each zone has multiple destinations and each segment of road forms part of the route for trips with different origins and destinations. Figure 7.1 illustrates the notation of the model. There are 2 SA1 origin zones (*i*), 3 UCL destinations (*j*) and 6 road segments (*k*) connecting the origins to the destinations. Each *i*, *j* and *k* number is a unique identifier for the network.

Notation used in the model is as follows:

- D_i is the set of destinations *j* that enter into the CI for origin *i*. Each origin has its own set of destinations, $j \epsilon D_i$. In Figure 7.1, both origins have the same set of destinations, $D_1 = \{j1, j2, j3\}$ and $D_2 = \{j1, j2, j3\}$

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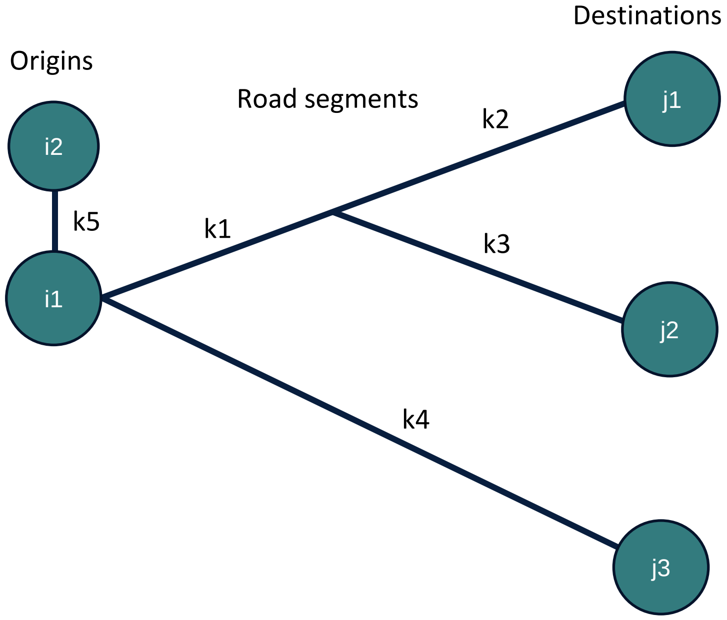
[33] With equity weights raised above one for zones below the threshold CI value, the higher demand for funds will reduce after-tax income. This will increase the marginal utility of income for all individuals, which reduces the value of travel time savings ($v = -\lambda/MU_y$ in the model), which, in turn, reduces benefits and hence investment in roads in zones with accessibility above the threshold. However, the effect would be small.

- R_{ij} is the set of road segments along the route from *i* to *j*. Each route *ij* has its own set of road segments, $k \in R_{ij}$. $R_{11} = \{k1, k2\}$, $R_{12} = \{k1, k3\}$, $R_{13} = \{k4\}$, $R_{21} = \{k5, k1, k2\}$, $R_{22} = \{k5, k1, k3\}$, $R_{23} = \{k5, k4\}$. The travel time between *i* and *j* is the sum of travel times on all the road segments that form part of the route from *i* to *j*, that is, $t_{ij} = \sum_{k \in R_{ij}} t(x_k)$.
- K_{ik} is the set of destinations, *j*, that are reached from origin *i* by travelling over road segment *k*. $K_{11} = \{j1, j2\}$, $K_{12} = \{j1\}$, $K_{13} = \{j2\}$, $K_{14} = \{j3\}$, $K_{15} = \{\quad\}$, $K_{21} = \{j1, j2\}$, $K_{22} = \{j1\}$, $K_{23} = \{j2\}$, $K_{24} = \{j3\}$, $K_{25} = \{j1, j2, j3\}$

Figure 7.1 Network to illustrate notation



Utility from accessibility for zone *i* is the logsum

$$U(A_i) = ln\ A_i = ln \sum_{j \in D_i} exp\left[\lambda \sum_{k \in R_{ij}} t(x_k)\right] P_j^{\mu}$$

The partial derivative of the logsum with respect to t_k is

$$\frac{\partial(ln\ A_i)}{\partial t_k} = \lambda\ \rho_{ik} \text{ where } \begin{cases} \rho_{ik} = \dfrac{\sum_{j \in K_{ik}} exp\left[\sum_{k \in R_{ij}} t(x_k)\right] P_j^{\mu}}{\sum_{j \in D_i} exp\left[\lambda \sum_{k \in R_{ij}} t(x_k)\right] P_j^{\mu}}, & k \in R_{ij} \\ 0, & k \notin R_{ij} \end{cases}$$

ρ_{ik} is the share trips out of origin *i* that travel over segment *k*.

Using the Figure 7.1 example to illustrate, in the case where segment *k4* links origin *i1* to just one destination *j3*, the share of trips from origin *i1* using segment *k4*, with $D_1 = \{j1, j2, j3\}$ and $K_{14} = \{j3\}$, is

$$\rho_{ik} = \frac{\sum_{j \in K_{ik}} exp\left[\sum_{k \in R_{ij}} t(x_k)\right] P_j^{\mu}}{\sum_{j \in D_i} exp\left[\lambda \sum_{k \in R_{ij}} t(x_k)\right] P_j^{\mu}} = \frac{exp[\lambda\ t_{k4}] P_{j3}^{\mu}}{exp[\lambda(t_{k1} + t_{k2})] P_{j1}^{\mu} + exp[\lambda(t_{k1} + t_{k3})] P_{j2}^{\mu} + exp[\lambda\ t_{k4}] P_{j3}^{\mu}}$$

Where road segment *k* is part of a road to multiple destinations from origin *i*, ρ_{ik} is the sum of the shares of trips from origin *i* to destinations *j* that travel over segment *k*. The list of relevant destinations is the set K_{ik}. The share of trips from origin *i1* using segment *k1*, with $D_1 = \{j1, j2, j3\}$ and $K_{11} = \{j1, j2\}$, 2 destinations, is

$$\rho_{ik} = \frac{\sum_{j \in K_{ik}} exp\left[\sum_{k \in R_{ij}} t(x_k)\right] P_j^{\mu}}{\sum_{j \in D_i} exp\left[\lambda \sum_{k \in R_{ij}} t(x_k)\right] P_j^{\mu}} = \frac{exp[\lambda(t_{k1} + t_{k2})] P_{j1}^{\mu} + exp[\lambda(t_{k1} + t_{k3})] P_{j2}^{\mu}}{exp[\lambda(t_{k1} + t_{k2})] P_{j1}^{\mu} + exp[\lambda(t_{k1} + t_{k3})] P_{j2}^{\mu} + exp[\lambda\ t_{k4}] P_{j3}^{\mu}}$$

The relationship $\frac{\partial(ln\,A_i)}{\partial t_k} = \lambda\,\rho_{ik}$ is used in the derivation below.

The weighted utility function for a representative individual on zone *i* with a transformation function $g(\cdot)$ is

$$U_i^* = U\left(y - \frac{\sum_k x_k}{Z}\right) + q_i\, g[U(A_i)]$$

where $\sum_k x_k$ is total road spending summed over all road segments in the network. Summing over individuals in all zones

$$\sum U_i^* = Z \cdot U\left(y - \frac{\sum_k x_k}{Z}\right) + \sum_i z_i q_i\, g[U(A_i)]$$

We now maximise the sum of weighted utilities across the network. Differentiating the weighted total utility function with respect to spending on one segment *k*

$$\frac{\partial \sum U_i^*}{\partial x_k} = Z\frac{dU(y)}{dy}\left(\frac{-1}{Z}\right) + \sum_i z_i q_i\, \frac{dg[U(A_i)]}{dU(A_i)}\frac{\partial[U(A_i)]}{\partial t_k}\frac{dt_k}{dx_k} = 0\ \forall k$$

Substituting in $\frac{dU(y)}{dy} = MU_y$, $\frac{dg[U(A_i)]}{dU(A_i)} = g'(ln\,A_i)$, and $\frac{\partial(ln\,A_i)}{\partial t_k} = \lambda\,\rho_{ik}$, the equity-weighted optimum investment condition becomes

$$\frac{\partial \sum U_i^*}{\partial x_k} = -MU_y + \lambda\frac{dt}{dx_k}\sum_i z_i q_i\, g'(ln\,A_i)\,\rho_{ik} = 0$$

Note that segment *k* can be an element of multiple sets R_{ij} for different origins.

Dividing though by MU_y and setting v=$-\lambda/MU_y$, the VTTS,

$$-v\frac{dt}{dx_k}\sum_i g'(ln\,A_i)\, z_i q_i \rho_{ik} = 1$$

The traffic from any given origin *i* on segment *k* is $z_i q_i \rho_{ik} = T_{ik}$, twice the total number of round trips (since q_i is one-way trips) out of origin *i* that travel over segment *k*. Substituting in T_{ik}, the optimum condition can be written as

$$-v\frac{dt}{dx_k}\sum_i g'(ln\,A_i)T_{ik} = 1$$

The weighted marginal benefit from spending an additional dollar on segment *k* is:

- the value of travel time, *v*, multiplied by
- the saving in travel time per vehicle on segment *k*, $\frac{dt}{dx_k}$, which is negative, multiplied by
- the sum over all origins of
  - the equity weight for origin *i*, $g'(ln\,A_i)$, multiplied by
  - the annual traffic volume on segment *k* from origin *i*, T_{ik}.

Say the average daily traffic on a road segment consisted of:

- 200 vehicles per day from zone 1 with an equity weight of 1.2,
- 100 vehicles per day from zone 2 with an equity weight of 1.5
- 50 vehicles per day from zone 3 with an equity weight of 2.0.

Then, the expression $\sum_i g'(ln\,A_i)T_{ik}$ would be (200 × 1.2 + 100 × 1.5 + 50 × 2.0) × 365 days per year.

The project would be accepted if the value of the weighted sum of the values of the travel time savings $-v\Delta t \sum_i g'(ln\ A_i)T_{ik}$ exceeded the costs.

Note that if all equity weights are one, the condition reduces to MBCR = 1, which is the optimal investment condition for maximum total utility and maximum economic efficiency.

7.4 Equity weighting functions

Two functional forms for equity weighting were suggested in Section 6.6 in the previous chapter, isoelastic and linear. In each case, the weights range from one at a threshold CI level to a maximum, w_{max}.

7.4.1 Isoelastic weighting function

With A_i as the CI for SA1 *i*, and $U(A_i) = ln\ A_i$, the isoelastic weighting function is

$$w_i = \begin{cases} min\left\{max\left[\left(\frac{ln\ T}{ln\ A_i}\right)^{\eta}, 1\right], w_{max}\right\}, & A_i > 1 \\ w_{max} & A_i \leq 1 \end{cases}$$

There are 3 parameters to set

- T, the threshold CI value at which weights begin to rise above one
- η, the elasticity, which determines how quickly the weight rises as accessibility falls
- w_{max}, the maximum value the weight can have.

Setting of the parameters is discussed below in Chapter 8.

To understand the implications of different parameter settings, the 18,491 SA1s with CIs and non-zero populations in the database were arranged in ascending order of each of the 3 types of CI. Weights were calculated with 3 elasticity values 0.5, 1.0 and 2.0 and 2 thresholds, all with a maximum weight of 3.0. The thresholds were set at the CIs for the 90th and 50th percentiles of the combined populations of the SA1s in the data (all SA1s outside the ABS Major Cities RA) from Table 3.4.

To create Figures 7.2 and 7.3, SA1s were sorted into ascending order of CI and cumulative population calculated for each SA1 by summing the populations for the SA1 in question and all SA1s with lower CI values. For Figures 7.2 and 7.3, the threshold was set at the 90th percentile of the total population of the SA1s in the data (outside the Major Cities RA). This means 90% of the population will reside in SA1s with a weight above one. Figure 7.3 shows only the leftmost section in Figure 7.2 up to the first one million of population to enable the impacts of using different CIs to be distinguished. Figures 7.4 and 7.5 show the same but with the threshold set at the 50th percentile. Weights above one (CIs below the threshold) occur for SA1s with a combined population of about 6.3 million people for the 90th percentile and 3.5 million for the 50th percentile.

The charts show that the choice of CI (employment, education or health trips) does not make much difference, which can be explained by the close relationships between the logs of the 3 CIs illustrated in Figure 3.11. For the upper range of the weights, the health CI produces the lowest weights, followed by the employment CI, then the education CI, with the latter 2 being quite close. The differences are greater with higher elasticities. The choice of elasticity is much more important than the choice of CI type.

Another observation from Figures 7.2 to 7.5 is that a higher elasticity, other things being equal, causes more of the population with the lowest levels of accessibility to have weights capped at the maximum level.

Figure 7.2 Weights with 90th percentile threshold for elasticities of 0.5, 1.0 and 2.0

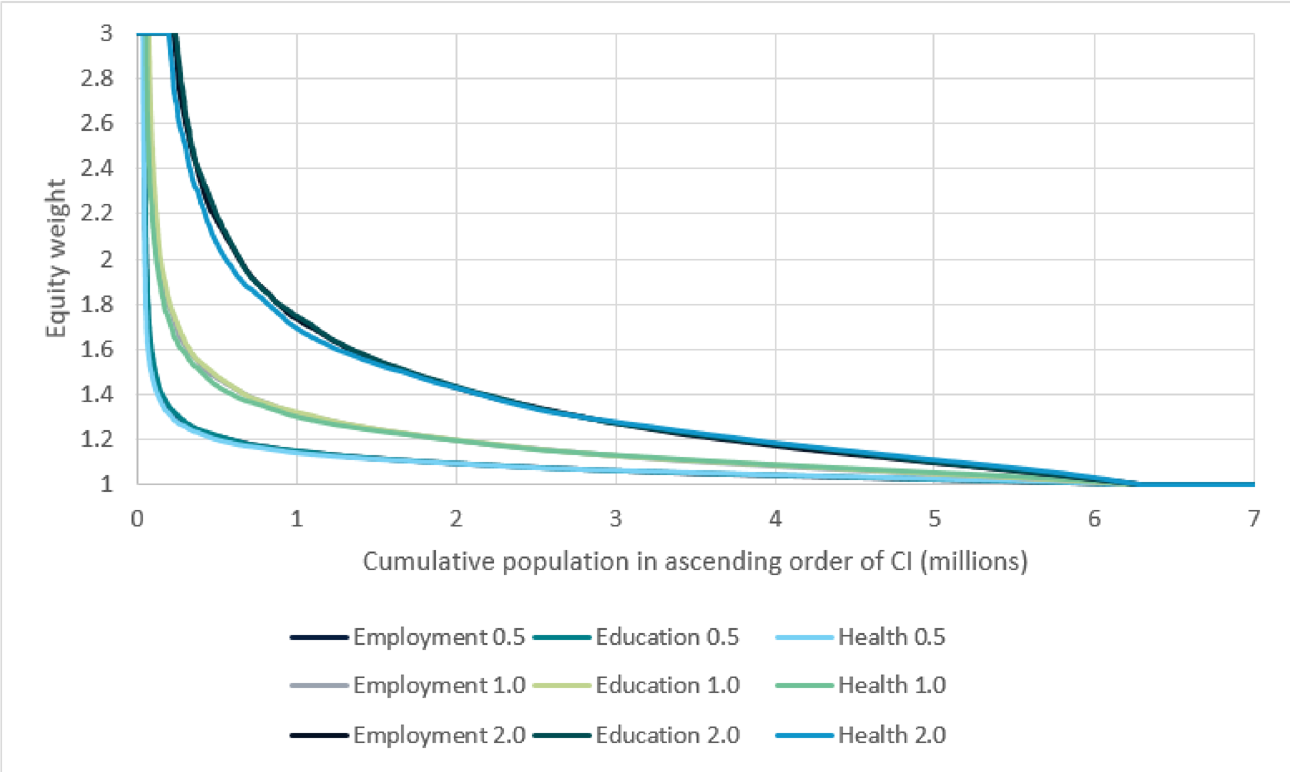


Figure 7.3 Weights with 90th percentile left section magnified for elasticities of 0.5, 1.0 and 2.0

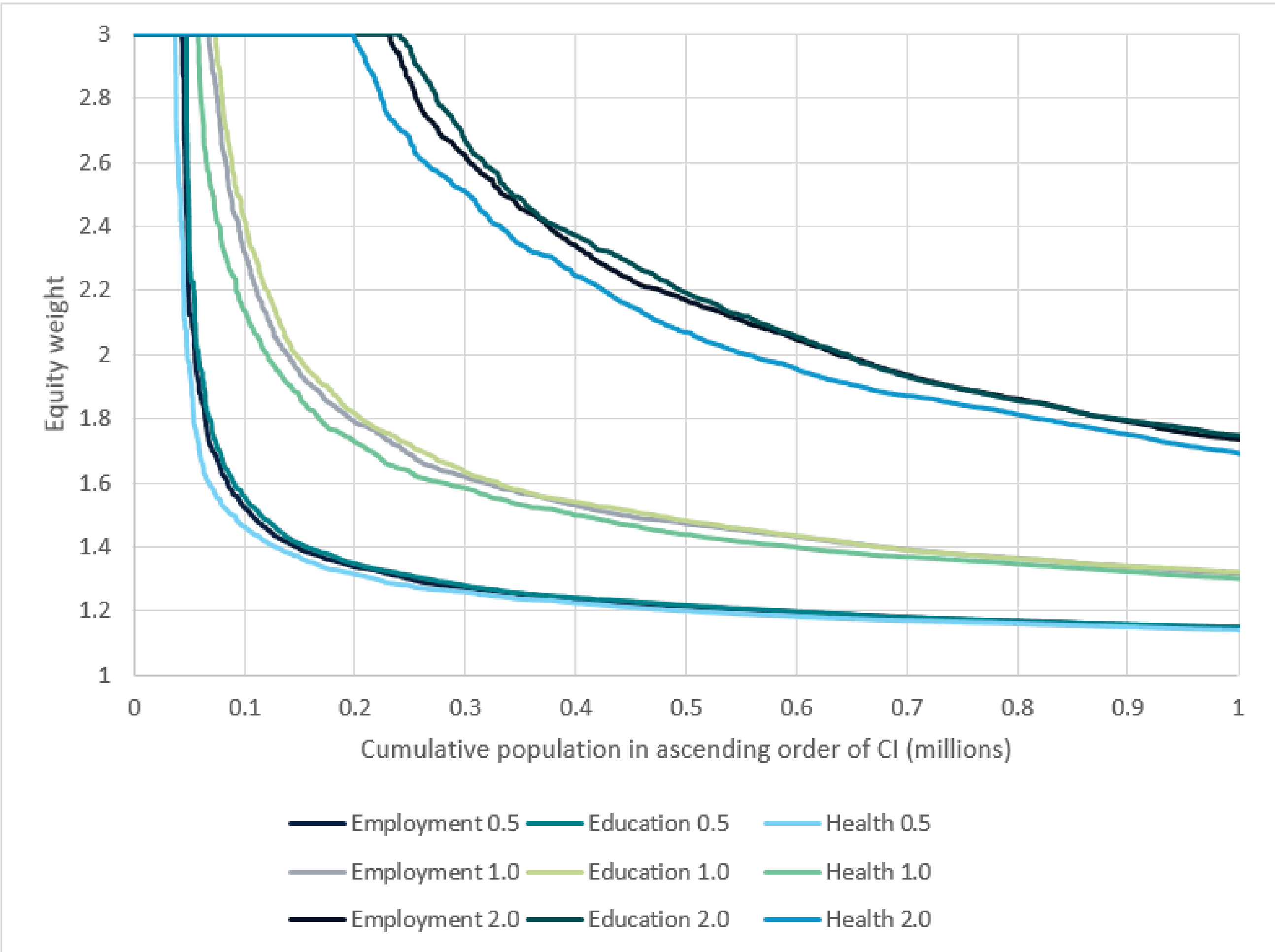


Figure 7.4 Weights with 50th percentile threshold for elasticities of 0.5, 1.0 and 2.0

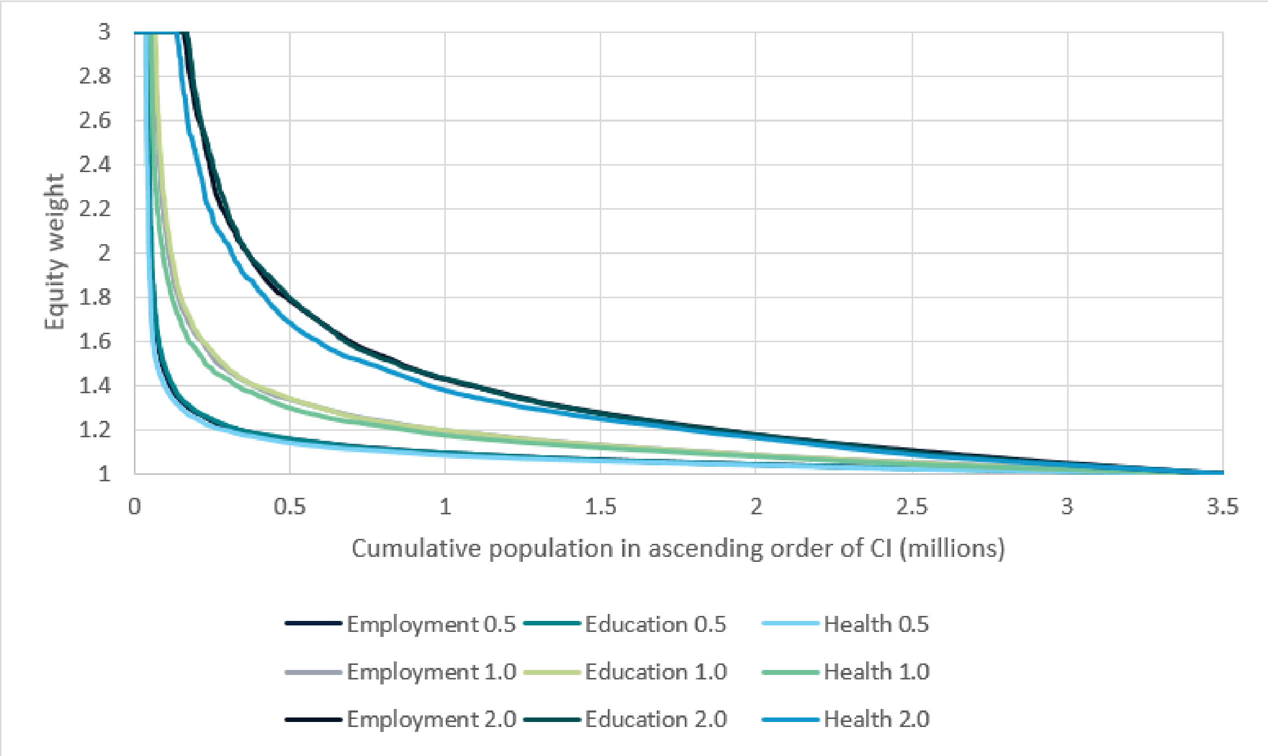


Figure 7.5 Weights with 50th percentile left section magnified for elasticities of 0.5, 1.0 and 2.0

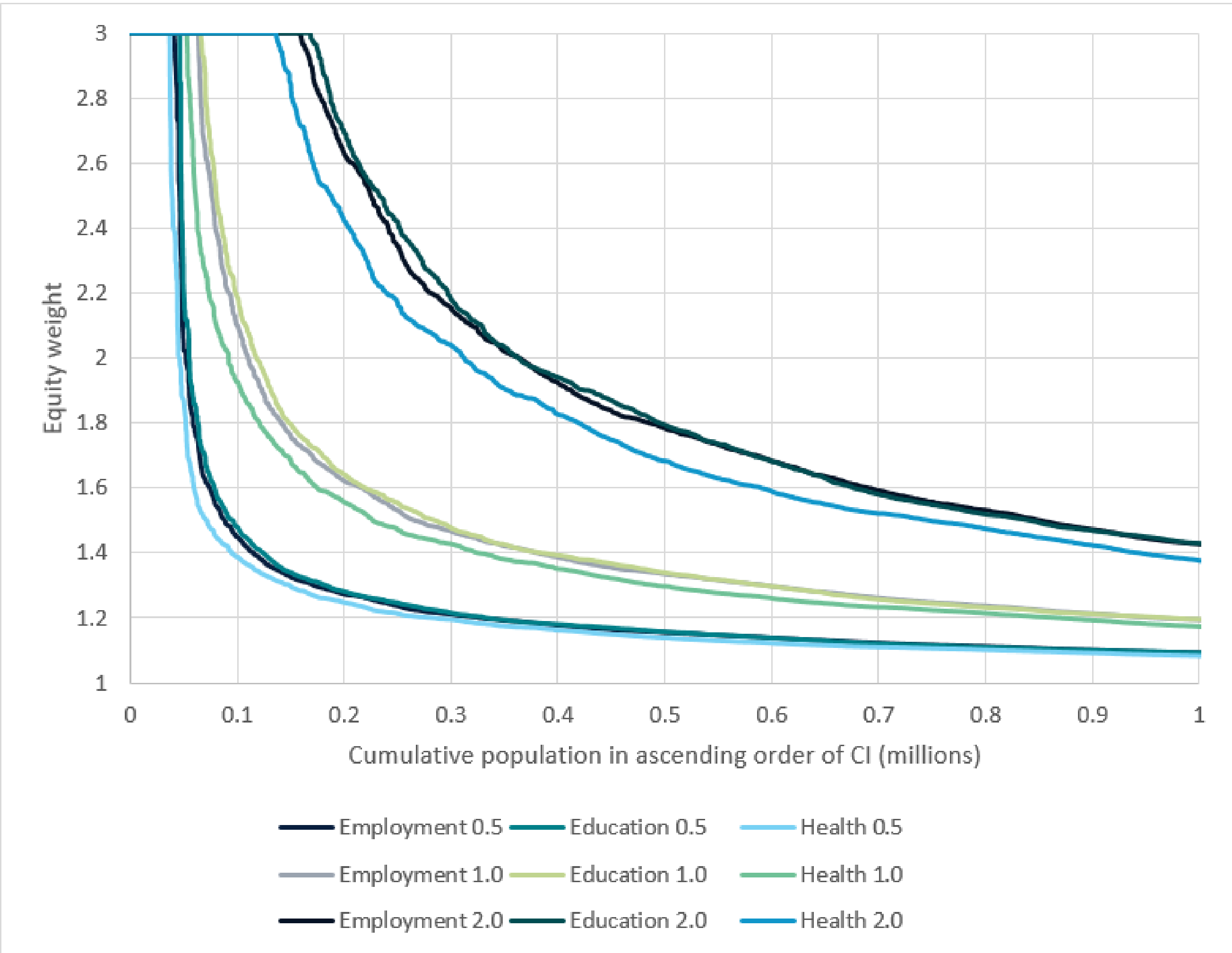
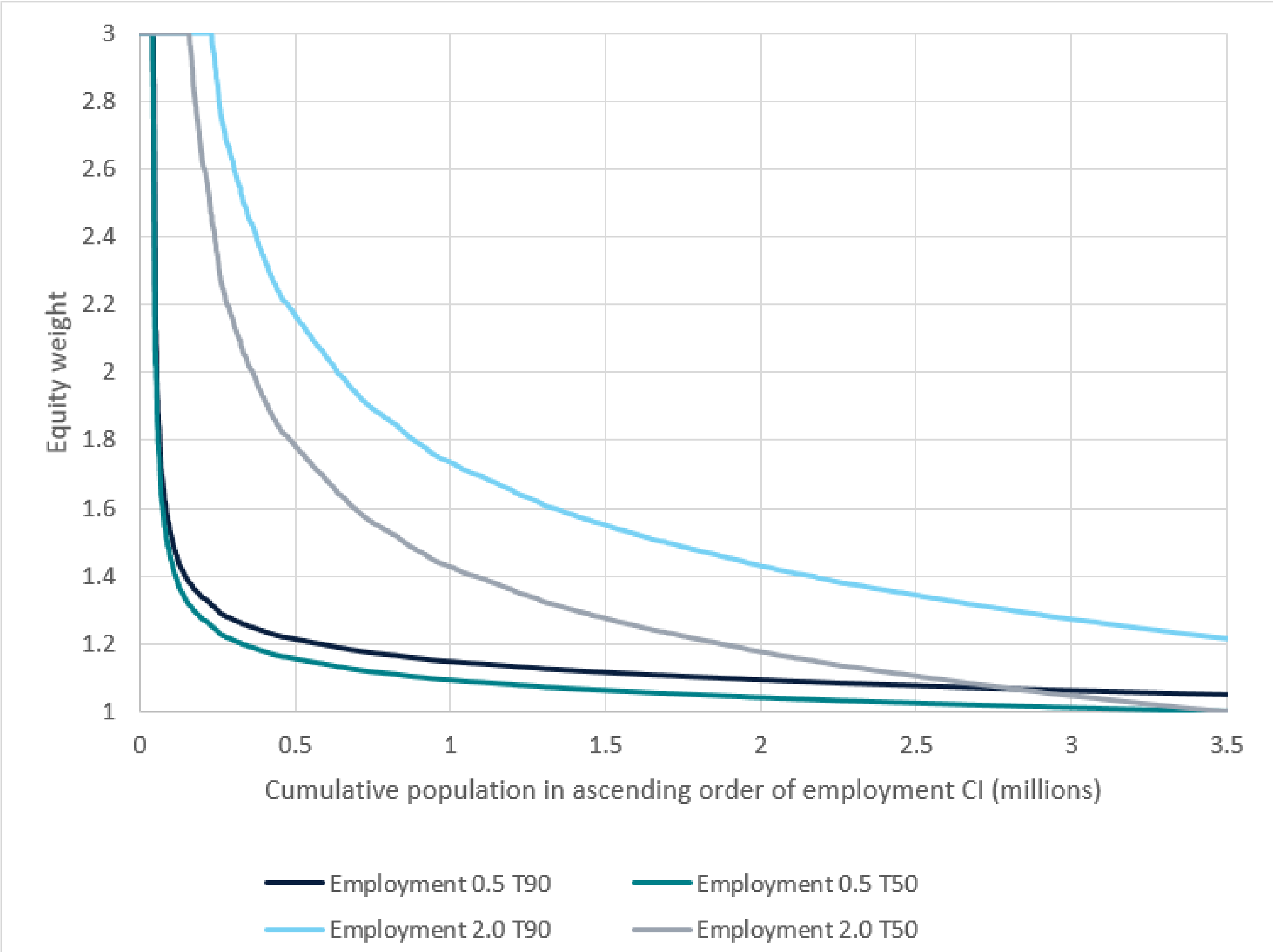


Figure 7.6 illustrates the impact of changing the threshold. It compares the weights for the employment CI alone at the elasticities of 1.0 and 2.0 at the 90th and 50th percentile of population thresholds. In addition to reducing the number of SA1s with weights above one, lowering the threshold reduces the weights for those SA1s below the thresholds, more so for higher elasticities.

Figure 7.6 Effect of reducing the threshold CI for elasticities of 0.5 and 2.0



Rather than specifying the elasticity, an option is to specify the CI value below which the maximum weight applies, A_m. The formula to find the elasticity given the threshold, T, maximum weight, w_{max}, and CI below which the maximum weight applies, A_m, is

$$\eta = \frac{\ln w_{max}}{\ln\left(\frac{\ln T}{\ln A_m}\right)}$$

Using the curve in Figure 7.6 with an elasticity of 2.0 as an example, the threshold is an employment CI of 2824.515 and the maximum weight of 3.0 is reached at a CI of just under 100. The required elasticity for $A_m = 100$ is

$$\eta = \frac{\ln 3.0}{\ln\left(\frac{\ln 2824.515}{\ln 100}\right)} = \frac{\ln 3.0}{\ln 1.7255} = 2.0140$$

7.4.2 Linear weighting function

While the isoelastic function for setting weights is theoretically elegant, other functional forms can be used. One option is a linear function between the threshold CI and the maximum weight. The points at the ends of the straight line segment need to be specified, ($ln\ A_m$, w_{max}) and ($ln\ T$, 1). The weighting function is

$$w_i = \begin{cases} min\{max[a - b \cdot ln\ A_i, 1], w_{max}\}, & A > 1 \\ w_{max}, & A \leq 1 \end{cases}$$

where *a* is the intercept and *b* the slope of the line. These parameters can be obtained as follows

$$b = \frac{w_{max} - 1}{ln\ T - ln\ A_m};\ a = 1 + b \cdot ln\ T$$

Figure 7.7 compares equity weights for the isoelastic and linear functions derived from logs of employment CIs, plotted against the logs of the CIs, which is utility from accessibility. The iso elastic functions are for elasticities of 0.5 and 2.0. The linear functions are straight lines joining the points where the isoelastic functions reach the maximum weight of 3.0 (A_m = 2.42 for the elasticity of 0.5, and 98.3 for the elasticity of 2.0) and threshold CI.

Figure 7.7 Isoelastic and linear equity weights plotted against the log of the connectivity index

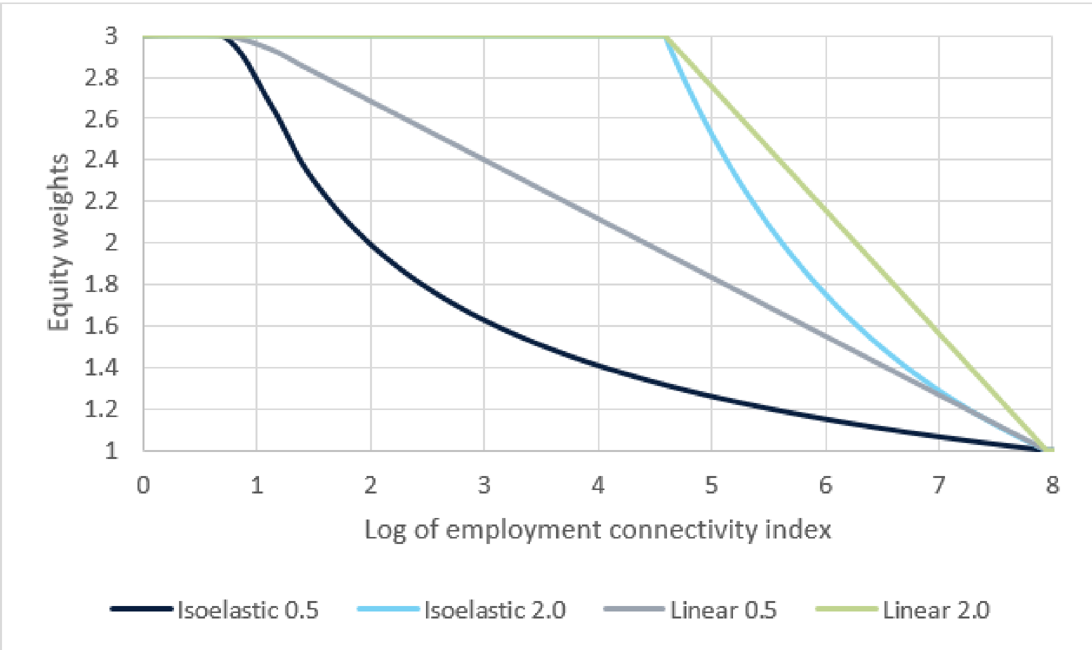


Figure 7.8 shows the same functions in Figure 7.7 plotted against the CI. Figure 7.9 shows these functions again but plotted against cumulative population.

Compared with the isoelastic weighting function, the linear weighting function leads to higher weights between the threshold CI (weight 1.0) and the CI at which the maximum is reached (A_m), giving higher priority to locations with intermediate CI levels.

7.5 Less detailed weighting systems

As traffic originating in each SA1 has its own equity weight value, implementation of the proposed equity weighting system is potentially quite data intensive and detailed. However, it is consonant with the methods in Chapter 3 and 4 for estimating induced traffic and social benefits, which are also undertaken at the SA1 level.

Possibilities for using population-weighted averages of CIs for the higher-level geographic aggregations — SA2, SA3, SA4 and RA — were investigated. It was found the variations in CIs within each area at the higher aggregations were quite large even at the SA2 level, which would cause the system to overlook localities with poor access. So it is recommended that weighting be done at the SA1 level.

Figure 7.8 Isoelastic and linear equity weights plotted against connectivity index

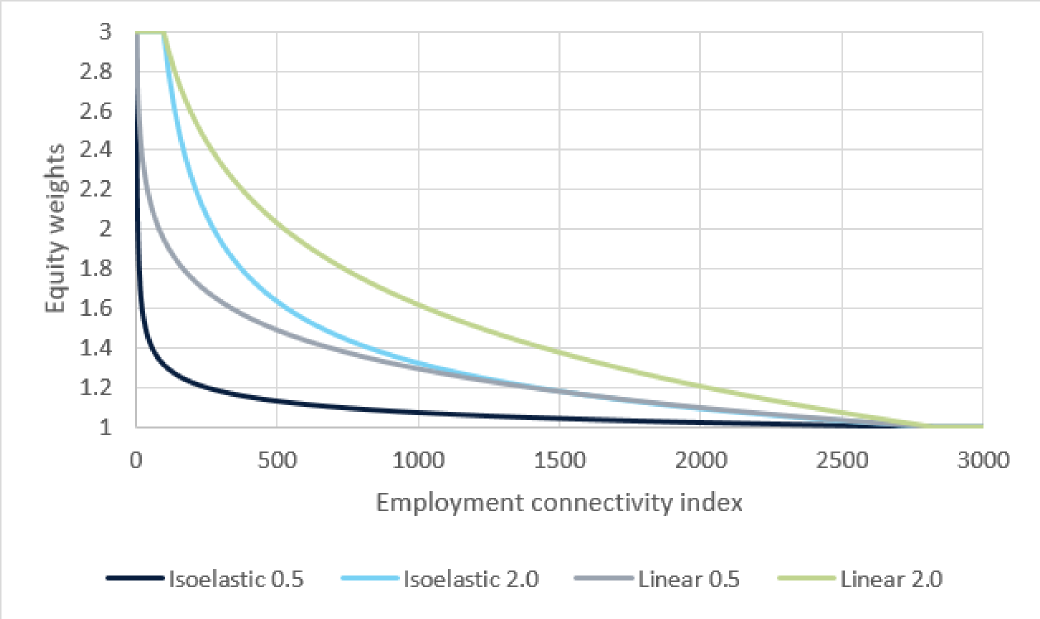
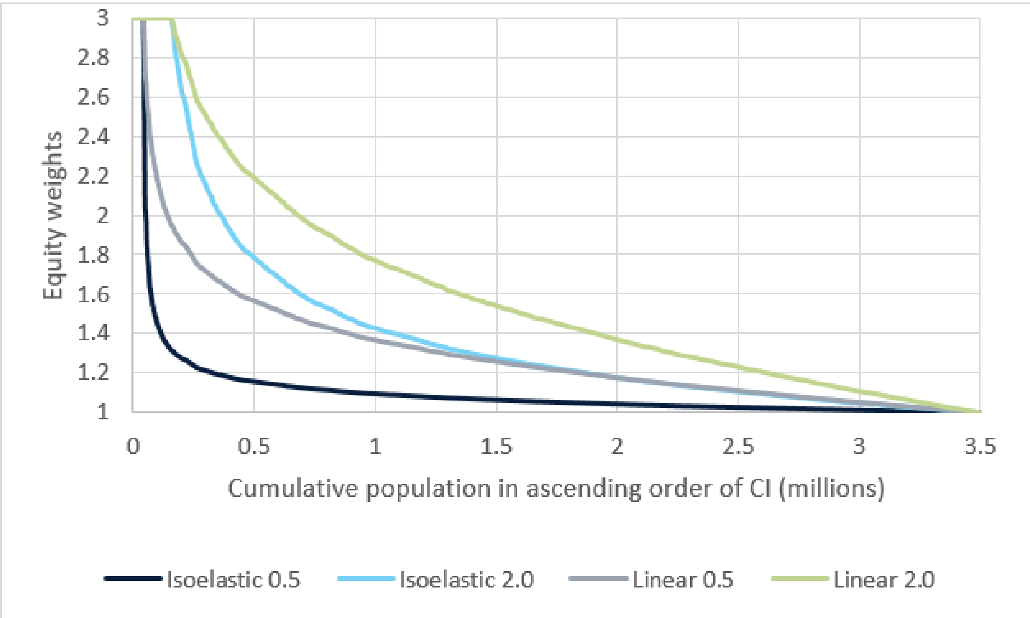


Figure 7.9 Isoelastic and linear equity weights plotted against cumulative population



7.6 Conclusion

Models have been developed in which individuals' utilities depend on their income and accessibility, measured by the CI. In the models, roads are funded by a uniform tax levied on all individuals and average incomes are uniform across zones. For such models, it was shown in Section 7.2 that the utilitarian and Dworkin hypothetical insurance approaches to equity both lead to the economic efficiency maximising outcome. A prioritarian weighting function applied to utility from accessibility is necessary to shift the optimum solutions towards a compromise between the economic efficiency and equity objectives, raising investment levels for zones with lower CIs.

In the detailed version of the model developed in Section 7.3, each zone has multiple origin–destination pairs and each road segment is traversed by traffic from multiple origins and destinations. It shows that, in a CBA with equity weights, benefits to traffic from each origin would be given the equity weight for that origin.

Isoelastic and linear equity weighting functions were discussed. In both cases, 3 parameters have to be set — a threshold CI above which the weight is one, a maximum permitted weight, and a CI below which the maximum weight applies (or alternatively, an elasticity for the isoelastic curve). The isoelastic weighting function rises very slowly as CI falls below threshold, then rapidly turns upward for very low CIs. The linear function rises more steeply at first, giving higher weights to SA1s with intermediate CIs.

The equity weights can be calculated from any of the 3 trip-purpose CIs (employment, education and healthcare). Which one is selected makes little difference to the weights. The employment CI was used in the examples in this chapter because with weights calculated from it lay in between the weights calculated from the education and healthcare CIs.

The choice of 3.0 as the maximum weight and thresholds at the 50th and 90th percentiles of populations outside major cities are for illustrative purposes only. They are not recommendations for setting the weighting function parameters. The next chapter discusses model calibration.

8. Implementation

8.1 Introduction

The methods presented in this report for estimating social benefits, WEBs and equity weights for CBAs of road projects in remote and regional areas involve mechanistic calculations. If applied without understanding of the context, there is a danger of unrealistic results. While CBA occupies a central position at the 'core of the assessment process' (ATAP 2021 F3, p. 15), the business case for a project will present to decision-makers an array of relevant information in addition to the CBA results (ATAP 2016b F4). A good CBA will describe how the project contributes to government objectives and addresses problems, how the community will be affected and the limitations and uncertainties of the analysis. There may be important non-monetised benefits and costs, which should be described, where possible quantifying them in physical units. There may be supporting analyses investigating environmental, distributional, employment, economic and land-use impacts. The components of project appraisal beyond the CBA calculations are well documented elsewhere in various guidelines.

Some matters that could arise when implementing the methods in this report are addressed in this chapter. They are calibration of the equity weighting function; geographic boundaries within which the methodology should be applied; whether equity weighting is appropriate for people who voluntarily reside in locations with poor accessibility; non-monetised impacts; flood resilience benefits; and demand forecasting where projects depend on large traffic increases for their benefits.

The requirement in guidelines for estimating WEBs, that practitioners present a 'narrative', has been adopted as a recommendation. The chapter provides a list of questions to address in a narrative for assessing road improvements using the methods in this report.

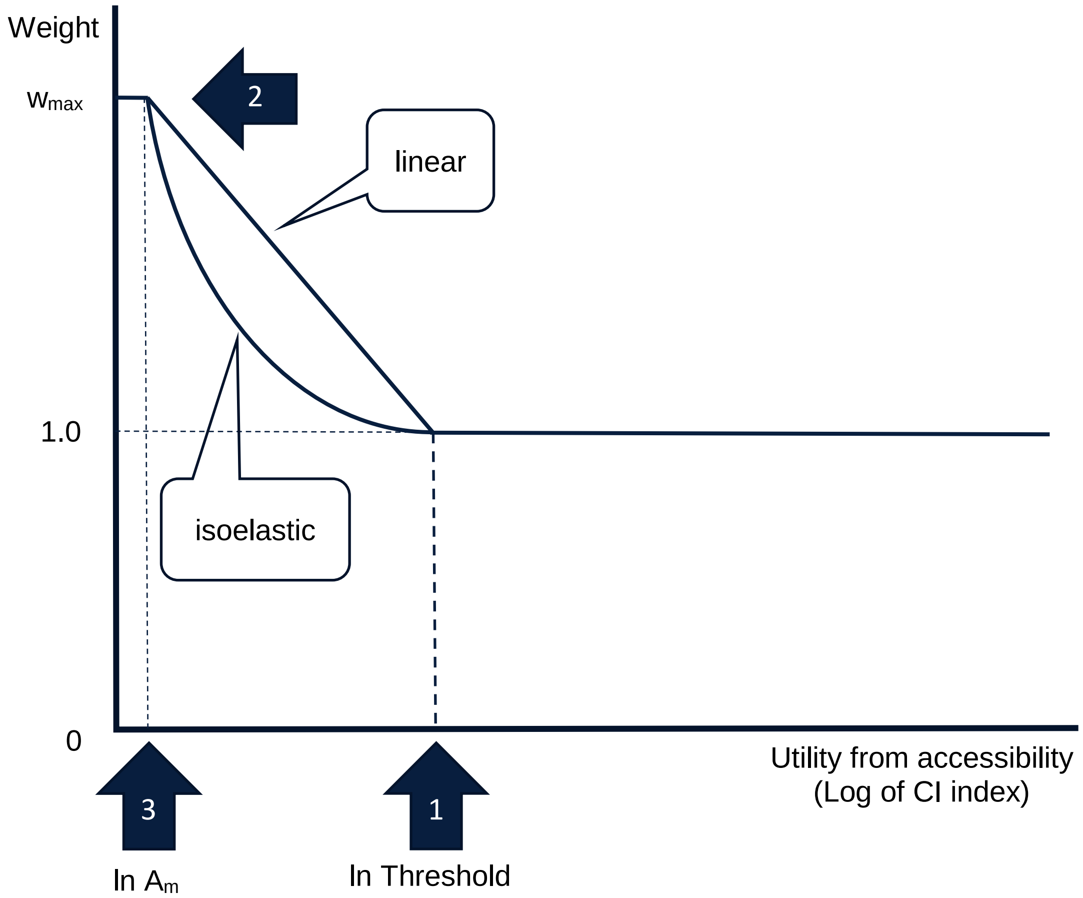
8.2 Calibration of equity weighting function

Calibration of the equity weighting function requires decision-makers to set 3 parameters, shown in Figure 8.1.

1. the threshold CI below which weights start to increase above one as CI reduces with remoteness
2. the maximum allowable value for the weights
3. the CI below which the maximum weight applies.

In effect, 2 points on the curve have to be selected, and the y-axis coordinate for the lower-right point is fixed at one. In the case of isoelastic function, the elasticity may be specified instead of the CI below which the maximum weight applies.

Figure 8.1 Parameters to set for the weighting function



As noted in Section 6.6, the maximum weight parameter is needed because, as the CI falls to one, the denominator of the isoelastic weighting function reaches zero. The maximum weight also serves the useful purpose of limiting spending on road projects with extremely poor returns from an economic efficiency viewpoint. The reciprocal of w_{max} is the lowest acceptable BCR. For example, with a maximum weight of 3.0, if all traffic on a road segment originated from SA1s with a weight of 3.0, the lowest acceptable unweighted BCR would be one-third. As discussed, spending on roads beyond economically efficient levels is a 'leaky transfer'. Due to the diminishing returns from spending to improve a given road segment, the extent of the leakage rises at an increasing rate as the MBCR is pushed further below one. Where low traffic volumes lead to low BCRs and small total benefits, decision-makers should consider whether there are more cost-effective ways to advance the wellbeing of the intended beneficiaries.

The parameter values for the equity weighting function need to be set based on

- the ethical judgements of decision-makers as to what is fair and reasonable, including long-term government objectives to raise or lower standards of road provision in remote and regional areas
- what can be afforded at the program level given budget constraints and considering alternative uses of funds
- precedents set by existing standards of road provision in remote and regional areas.

The higher equity weights are set, the greater will be the demand for road spending. Equity weights that lead to higher levels of investment in remote and regional roads, will have budgetary impacts unless funds are shifted from parts of the road system with CIs above the threshold. Governments may wish to ensure that application of the equity weights does not lead to more projects passing the weighted CBA test than they can afford to fund.

While the normative policy choices of decision-makers, tempered by availability of funds, should be the overriding determinants of equitable road standards, the precedents set by existing standards of road provision cannot be ignored, even if they are the result of past ad hoc decisions. Existing standards are what the community is accustomed to and set a baseline for decisions to raise or lower standards of road provision. Stanley & Starkie (1983) argued that formation of community expectations as to road standards is dynamic, that is, the level of performance is continually reassessed in the light of what has been achieved and what is achievable. People compare the standards of roads in their own regions with those in other regions with similar economic, social and environmental characteristics.

> Equity in this arena … involves a comparison between the community's view of the road system it has, the road systems of other regions, and the road system to which it believes it is entitled. It encompasses the concept of wanting something, not because it is needed, but because someone else already has it. … there will be pressure from a community to improve its roads until the perceived limit of entitlement is reached. That perceived limit is likely to be set by notions of equity. (Emmerson & Miller 1983, p 83)

To calibrate the equity function, a road agency could develop a set of representative road projects with BCRs below one in a range of locations with different CIs to determine the impacts of equity weighting on BCRs. The projects could be obtained from a mix of recent past CBA reports and hypothetical projects with realistic benefit estimates and investment costs. The question to address is: if these projects are considered desirable on equity grounds taking into account decision-makers' preferences, affordability and existing standards, what is the size of the weight above one needed to raise the BCR to one?

A variation on this approach would be to examine data on the existing standards of roads provided (gravel, sealed, 2-lane narrow, 2-lane wide, addition of sealed shoulders, duplication) and traffic levels, to determine the typical AADT levels at which one standard transitions to the next — for example, sealing a gravel road when the AADT exceeds 300 vehicles per day, duplicating when AADT exceeds 8,000 vehicles per day — in locations with different CI levels. Then, given the capital costs of each transition, back-calculate the equity weights needed to obtain a BCR of one, hence, justifying the existing standards given CI levels. Alternatively, a set of target standards could be set for roads with specified AADT and CI levels, and equity weights set to make these just achieve BCRs of one. (See ATAP 2019a 05 on setting road standards.)

During an initial period, CBAs could be presented with benefits adjusted with more than one set of equity weights to see how the weights will impact on the overall demand for funds and relativities between projects of different types and in different locations.

The ABS RA classifications of SA1s could be used for benchmarking the CIs for the purposes of setting the weighting function parameters. An example of using RAs and the employment CI to set the parameters is as follows:

- *Setting the CI threshold*: 75% of the population in the Outer Regional RA have an employment CI of below 3,004. Rounded off, 3,000 could be set as the threshold for applying the equity weights. Since all SA1s in the Remote and Very Remote RAs have employment CIs below 3000, they would all receive weights above one. 38% of the population in the Inner Regional RA also have a CI below 3,000. Of the entire population outside the Major Cities RA, 53% have a CI below 3000. This threshold is close to the 50% threshold for all the population outside major cities used in the examples in Chapter 7.
- *Choose between the 2 functions based on weights for intermediate CI values*. The isoelastic function will concentrate road upgrading in the least accessible areas and might be preferable if an objective is to reduce social exclusion in the most remote areas. The linear function will spread the upgrading works towards areas with intermediate levels of accessibility. The isoelastic function would favour improving accessibility for remote First Nations communities while the linear function would favour rural areas in general where agriculture and mining are the main economic activities. Other functional forms could be considered.
- *Setting the CI for the maximum weight*: Say the maximum weight of 3.0 was adopted to apply to employment CIs below the level for the 25% of the population in the Very Remote RA with the lowest CIs. The CI for the maximum weight would be 3.55. A small percentage of the population in the remote RA, 1.4%, also have CIs below 3.55. For the same threshold (T), maximum weight (w_{max}) and CI below which the maximum weight applies (A_m), the isoelastic function will lie below the linear function for all CIs between A_m and T. This is illustrated in Figure 8.2. In the numerical example, 75% of the population in the

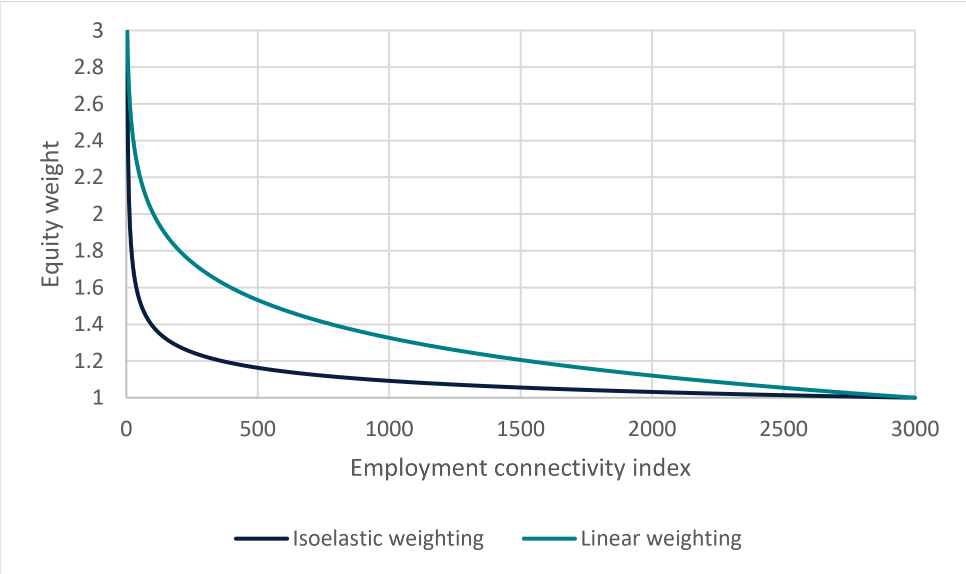
Remote RA have an employment CI below 656. At the CI of 656, the weight is 1.13 with the isoelastic function and 1.45 with the linear function. As the isoelastic function is below the linear function for all CIs between A_m and T, a higher level of A_m might be chosen for the isoelastic function to compensate.

- *Fit isoelastic and linear weighting functions*: The decisions the 3 parameters, T, w_{max} and A_m, yield 2 points on the weighting function — (T = 3000, weight =1) and (A_m = 3.55, w_{max} = 3.0). These 2 points define a unique isoelastic function and a unique linear weighting function. The elasticity for the isoelastic function is 0.5959. The parameters for the linear function are a = 3.376 and b = 0.2968. The 2 functions are illustrated in Figure 8.2.

The formulas for estimating the parameters for the isoelastic and linear functions are:

$$\eta = \frac{ln\, w_{max}}{ln\left(\frac{ln\, T}{ln\, A_m}\right)};\, b = \frac{w_{max} - 1}{ln\, T - ln\, A_m};\; a = 1 + b \cdot ln\, T$$

Figure 8.2 Isoelastic and linear equity weight functions



Consistency in application of equity weighting is desirable within a jurisdiction, necessitating a single equity weighting function for the whole jurisdiction. As each state and territory will have its own policy preferences for equitable road accessibility, budgetary constraints, and existing standards, the equity weighting functions and parameters will differ between jurisdictions. Each state and territory government would have to establish its own equity weighting function to apply to assessments of road improvements they are considering funding. For decisions by the federal government to contribute funds to projects, an Australia-wide equity weighting would be needed. CBA reports for projects funded by multiple jurisdictions would have to include weighted results for the equity weighting function and parameters for each jurisdiction.

8.3 Boundaries for applying the methodology

The methods developed in this report are aimed at remote and regional roads, not roads in metropolitan areas. The CIs have been estimated excluding the Major Cities RA as defined by ABS. The methods are also unlikely to be warranted in the Inner Regional RA. The social benefit methodology is based on market imperfections considered likely to occur only in remote areas. The equity weighting system sets a threshold for the accessibility level before which the weights start to rise above one, and the rise is gradual. A road agency might want to set a boundary outside of which the methods should not be applied.[34]

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[34] This does not rule out application of equity weighting in urban areas to address social exclusion, but an alternative accessibility measure would need to be developed.

The ABS RA boundaries are unlikely to be suitable. As shown in Tables 3.2 and 3.3 and Figure 3.9 in Chapter 3, there is overlap in the CI scores between RAs. There are SA1s with low CI scores in all 4 RAs outside major cities.

The boundary could be set as including all traffic originating in all SA1s with a CI below the threshold where the equity weights begin to rise above one. Since weights slightly above one will have little effect on BCRs, a boundary could be set at a weight above one. From the curves in Figure 8.1, if the boundary was set at a weight of 1.1 or more, the employment CI would have to be below 920 for the isoelastic function and 2,144 for the linear function compared with a threshold of 3,000 where the weight is one.

Degrees of social exclusion, as defined in Chapter 3, assessed qualitatively, could be a consideration in setting the boundaries as well as the form and parameters of the weighting function.

8.4 Voluntary isolation

The discussion of Dworkin's theory of justice in Section 6.5.3 referred to his distinction between 'option luck' and 'brute luck' as a criterion for determining whether compensation is due to people with lower levels of wellbeing. Option luck is the result of deliberate and calculated gambles. Brute luck is how risks fall out, such as being born with a disability. Dworkin argued that there should be no redistribution between the winner and loser of a gamble because the difference in wellbeing is caused by a risk they both chose to take upon themselves and could have declined. The circumstances under which option luck warrants compensation and the extent of such compensation is debated by philosophers (Knight 2013). It raises the question of whether benefits accruing to people who live in remote and regional areas voluntarily ought to be given equity weights above one.

Several authors in the transport discipline have questioned whether people who choose to live in areas with poor access deserve special consideration (Van Wee & Geurs 2011, p. 353; Van Wee 2022; Loader & Stanley 2009, p. 107). Some people may prefer living in a rural area because of the lifestyle and lower housing costs. The gloomy statistics for regional Australia cited in Chapter 4 of this report do not paint the full picture. There are many positive aspects to living in remote and regional areas including higher levels of life satisfaction compared with those in urban areas (Wilkins 2015); social cohesion; community participation; volunteering; and informal support from within communities (Ziersch et al. 2009). To keep their environment quiet and peaceful, some residents might not even want road access improved. Some people may be attracted by economic opportunities, for example, in mining and agriculture. Some might have originally moved to a rural area voluntarily, but populations and services in the area have declined and they lack the resources to move elsewhere.

One of the definitions of social exclusion given in Chapter 3 was people or population groups being excluded from a certain minimum level of participation in location-based activities in which they *wish* to participate. But how strong does that wish have to be (Van Wee & Geurs 2011, p. 353)? The question of voluntary or involuntary is not black and white but a matter of degree (Van Wee 2022). Loader & Stanley (2009) maintain that a basic level of access should be available to all regardless, but they are writing about public transport services in urban areas where the costs of better service levels are manageable.

The CIs and equity weights proposed in this report take no account of whether or not poor accessibility is voluntary. People voluntarily living in remote and regional areas are likely to be employed and more aware of the value of trips for education and health purposes. Hence, the market imperfections that underly the social benefits concept may not apply to them. Analysts applying the methods in this report should investigate the local context of the road project being appraised, and form a view as to whether people in SA1s with low CIs live there voluntarily or not, whether they live there for lifestyle or economic reasons, and consider whether any special consideration is warranted. The assessment should form part of the 'narrative' proposed below and could influence whether social benefits are estimated and weights applied.

8.5 Flood resilience projects

Benefits from improvements to flood resilience are only realised in times of exceptionally high rainfall. The higher capital costs of building causeways and higher bridges must be offset against the flood resilience benefits.

Assessment of flood resilience benefits is probabilistic. Expected values of benefits can be estimated from probabilities of the frequency, severity and duration of floods. ATAP (2019b O2) provides a methodology. Benefits to road users include savings in waiting time, use of diversion routes, trip postponement or cancellation, use of air transport, injury or loss of life for people attempting to cross flooded infrastructure, and accommodation costs. For road agencies, better flood resilience can reduce damage to infrastructure and clean-up costs. Non-monetisable impacts include loss of perishable goods, emergency services costs, excess inventories and loss of access to essential services.

Where a road improvement reduces missed trips for education, health and employment purposes due to flooding, the social benefit values from Chapter 4 can be applied, as illustrated in the worked examples in Appendix B. The worked examples suggest that social benefits from reducing numbers of missed trips due to flooding can be substantially more than the social benefits from induced trips. Equity weights derived from CIs could be applied to flood benefits.

8.6 Freight

The accessibility, social benefit and equity weighting methods in this report are aimed at individuals making regular trips by car. They do not apply to freight vehicles, with the exception of the WEB for output changes in imperfectly competitive markets (WB3) in Section 5.4.

8.6.1 Lifeline freight routes

Austroads (2024) addresses

> lifeline freight routes [that] do not deliver positive outcomes in conventional cost–benefit analysis assessments due to their relatively low traffic levels but have high value to the communities and regions they support. (p. i)

Lifeline freight routes have limited alternative routes, are at risk of temporary closure due to natural disasters, and, when closed, impose significant costs. These costs include:

- productivity losses from increased travel times, vehicle damage and increased operating costs as drivers are forced to take alternative routes or modes of transport
- social or financial costs where communities become fragmented, isolated and disconnected as a result of road closure, which also prevents delivery of essential supplies and access for emergency services (Austroads 2024, p. 1).

Austroads (2024) introduces a spreadsheet tool to help identify, categorise and rank lifeline freight routes and to rank investments to reduce risks on different routes using multi-criteria analyses. The ABS Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) is an input to the ranking process. The IRSAD measure is calculated at the SA1 level and is a weighted sum of 25 variables including factors related to income, education, employment, internet access, housing, and family structure.

Most of the costs of road closure mentioned in Austroads (2024) would be estimated in a conventional CBA using the methods for estimating flood resilience benefits in ATAP (2019b O2). To the extent that our CIs and IRSAD scores are correlated and local car trips are benefitted by the investment project under consideration, there would be some agreement between what our approach and the Austroads (2024) approach are trying to achieve. However, the 2 approaches are quite different.

8.6.2 **Damage to livestock**

Damage to livestock occurs as a result of dust inhalation and jarring on unpaved or unsealed roads. The Queensland Transport and Main Roads CBA Manual (QTMR 2021, pp. 4.96-7) provides guidance for estimating the benefit from reducing this damage. Unit benefit values per kilometre are provided for articulated and B-double trucks and road trains for upgrades from unsealed/formed to gravel/paved sealed road ($0.609), from paved to sealed ($0.304) and from unsealed/formed to sealed ($0.909). The dollar values quoted are unchanged from the 2011 edition.

8.7 Non-monetised social benefits

A good CBA will identify and describe non-monetised benefits and costs, where possible quantifying them in physical units. The methods in Chapters 3 and 4 aim to shift education, health and employment benefits from the non-monetised to the monetised category. The education and employment social benefit values per trip include an allowance for consequent reductions in crime and improvements in health and social cohesion (non-pecuniary externalities). However, these benefits, along with the safety and secondary benefits, can be reinforced in the CBA report through qualitative discussion.

ATAP (2021 F3) recommends use of the Appraisal Summary Table technique to bring together all the relevant information to assist decision-making. Initially developed by the UK Department for Transport, the Appraisal Summary Table has been adopted by some Australian jurisdictions. The Appraisal Summary Table presents information on all impacts, monetised and non-monetised, in a single table with subjective ratings for the size and direction of each impact and the level of confidence. For example, the qualitative non-monetised rating system could describe impacts as being either positive or negative, and whether the scale of the impact is neutral, small, moderate or large. The impacts can be grouped in triple-bottom-line format — economic, social and environmental. Decision-makers can make a judgement based on the information presented about the overall merit of a project. The Appraisal Summary Table is a non-quantitative form of multi-criteria analysis. It does not produce an overall single score as an indicator of a project's overall merit.

8.8 Demand forecasts and penetration roads

Demand forecasts for non-urban roads are typically made by assuming linear growth of past AADT levels. The Chapter 3 methodology enables forecasting of small amounts of induced traffic to add to the projection of existing traffic. As this induced traffic is linked to population numbers and has no history from which a linear growth increment could be inferred, it is recommended that demand projections be based on population projections in the origin SA1s, preferably using medium or low projections to be conservative.

CBAs of upgrades to major roads and altogether new road links may assume a step-change in demand dependent on an industrial development or new population centre eventuating. The assumption is: 'build it and they will come'. Regional variations in the supply of roads can influence regional economic development but Brayan et al. (1997, p. 228) and the studies they cite warn that

> While infrastructure improvements are usually necessary to promote development in periphery areas, they are insufficient on their own. Other policy instruments are necessary to complement road improvements as part of a regional development package.

A high level of uncertainty surrounds traffic forecasts dependent on new economic activity eventuating. There is a serious risk that the new activities will not materialise and anticipated project benefits will not be realised, wasting resources on unproductive infrastructure. Such uncertainty can be addressed in a degree through:

- market sounding by canvassing potential investors, developers and buyers
- undertaking financial analyses from a private sector viewpoint to test whether the foreseen economic opportunities are likely to be commercially viable
- having future private sector users of the infrastructure contribute to project funding or commit to pay compensation if they fail to invest in industrial developments that would use the infrastructure

- staging investments to maximise the ability avoid further commitment if the expected economic development does not occur (the 'real options' approach, see ATAP 2020 T8).

Applying the rule-of-half to estimate benefits from a step change in demand may not give plausible results because of the large gap between base-case and project-cast quantities and generalised costs. Harberger (1972, pp. 254-8) discussed 'penetration roads' which he defined as a road built into an area to which access by motor vehicles was previously impossible. The consumers' surplus benefit is the whole area under the demand curve minus the generalised costs of travel. Assumptions about the height and shape of the demand curve over a large part of its length will have a major impact on the size of the benefit (ATAP 2022a T2, pp. 41-2).

Harberger suggests the following options for estimating the whole area under a demand curve:

- If the road serves an isolated mine and the traffic using the road is exclusively or almost exclusively associated with operation of the mine, then the mine owner should bear the costs of the road. They would have the incentive to do so if benefits exceeded costs. There should not be any need for government investment.
- Where there are multiple potential users who cannot reasonably be expected to come to a cost sharing agreement to resolve the 'free-rider' problem, there may be a role for government. The benefits of the road could be estimated from the forecast increase in the value of land minus all the costs of improvements to the land in the project case.
- The benefits could be estimated to be the total revenue from mining or agricultural output made possible by the road, minus all input costs (land improvement, labour, fertiliser, costs of transporting both inputs and outputs, and complementary government investments to provide services).

Harberger (1972, p. 258) noted that estimation from total consumers' surplus, land value changes, and value of output are 3 alternative ways to measure the same benefit. Using more than one will lead to double or triple counting of benefits.

8.9 Disinvestment

The methods in this report can be applied to appraisal of disinvestment and road maintenance. Falling populations and funding shortages could lead road agencies to consider allowing a road to drop to a lower standard. Allowing a sealed road to deteriorate to gravel, or gravel to unpaved, can achieve considerable savings in maintenance costs (Scholer 1986, p. 189).

8.10 Maintenance

Economically optimal road maintenance was addressed in Section 2.3. Modelling to optimise maintenance spending could be undertaken by minimising the sum of the present value of road agency costs and road user costs with the latter multiplied by equity weights depending on the origins of the car traffic. As with capital investments, this would result in an MBCR below one, with more frequent and more intense maintenance treatments than otherwise (BITRE 2023; Harvey 2024).

8.11 Presentation of weighted CBA results

It is recommended that CBA results adjusted with equity weights never be reported separately from the results of the CBA without weights. This is a standard recommendation for weighted CBAs in CBA guidelines (ATAP 2022a T2, p. 79; Dobes 2009, pp. 22-3). It ensures that decision-makers are made aware of the amount of economic efficiency gains forgone in order to promote equity objectives.

8.12 A narrative

UK guidelines for estimating WEBs require project proponents to present an 'Economic narrative' with CBAs articulating why the transport investment is needed to achieve economic objectives and how it is expected to achieve these (UK DfT 2025a, b & c). The ATAP (2023 T3) guidance for estimating WEBs adopted the idea. The expectations in the UK guidance for the content of the economic narrative are quite wide-ranging and some of the requirements would be met by the 'strategic merit test' and 'appraisal summary table' recommended in ATAP (2021 F3).

This report recommends that CBAs applying any or all of the social benefit, WEBs and equity weighting methods in the report, explain and justify the applications with a narrative. Some specific questions to address are:

- Where social benefits or WEBs are claimed, the supporting economic theory should be explained, with the relevant market imperfections, giving context-specific evidence. The explanations in Chapters 4 and 5 of this report provide the foundation for generating this part of the narrative.
- Where the methodology in Chapter 3 forecasts additional trips for education, health and employment purposes, are the trips likely to eventuate? For the origin SA1 for which social benefits are being claimed, are there pre-schools, primary and secondary schools, tertiary education centres with the right courses, medical centres of the right type, and jobs for low-skilled workers in the locations to which the road project will improve access? (Lucas et al. 2016, p. 486)
- Are there other factors that inhibit people from taking advantage of the improved road such as social problems, or unwillingness or incapacity to travel to the destinations made more accessible?
- Are the beneficiaries living in an area of poor access because of ties to the land and people of the area, inability to relocate, or are they there to enjoy the lifestyle or take advantage of economic opportunities. This is the question of voluntary or involuntary isolation raised in Section 8.4 and might indicate whether social benefits and equity weights are appropriate or not.
- The allowances for externalities of improved health, reduced crime, more informed political debate, strengthening of civil society and social cohesion in the social benefit values for education and employment are generic and so do not account for differences between sites. Are these externalities likely to be realised in practice and to what extent? If the area already has low crime rates, good levels of educational attainment, and people leading healthy lifestyles, there may be little improvement. Where there are major problems, the monetary allowances could understate the true social value. A qualitative assessment should be made.
- Where employment social benefits are claimed, is any of the additional employment created displacing existing employment? If so, benefits should be claimed only for the net increase in employment.
- Each of the 3 WEBs in Chapter 5 that are unique to remote and regional areas — change in competition (WB4), monopsony labour markets and involuntary unemployment — needs to be justified with details on the assumptions, data and sources of data. To claim the monopsony labour market and involuntary unemployment WEBs, it was suggested in Chapter 5 that an economic impact study may be needed. The narrative would draw on such a study.
- Are there likely to be impacts on the availability of local services? If people use the improved road to travel outside the town to take advantage of services and shops that are less expensive and more varied, will that lead to a reduction in locally available services and shops? This would disadvantage local people without access to car transport. This possible impact is outside the methods developed in the report, but if considered likely, ought to be addressed in the CBA report.
- Are there more cost-effective ways than road improvement to achieve non-economic objectives such as spending directly on education or healthcare? This is another consideration outside the methods developed in the report, but again, the question should be raised.

8.13 Conclusion

This chapter has addressed a number of matters that will arise when applying the methods developed in the report. The methodologies are not intended to become standard practice for CBAs of road projects, but to apply only to a subset of projects in remote and regional areas. Jurisdictions adopting some or all the methodologies should set clear boundaries within which application is appropriate.

Suggestions to assist with setting boundaries and calibration of an equity weighting function have been advanced in the chapter, taking to account equity objectives, affordability and existing standards. The form and parameters of the weighting function and boundaries are for road agencies to determine, not practitioners undertaking CBAs. Practitioners should take them as given, just as for discount rates.

It is recommended that road agencies insist that applications of the methods be accompanied by a ‘narrative’ that describes and justifies the theoretical basis and addresses a range of questions about the context in which the methodology is being applied. A narrative will help to ensure that the mechanical calculations of benefits are grounded in reality and therefore credible.

9. Conclusion

In common with other network industries with community service obligations, governments provide roads in remote and regional areas beyond the levels that could be justified on economic efficiency grounds for social and equity reasons. This report has developed methodologies to supplement CBAs for road improvements in remote and regional areas with the aim of improving the efficiency, equity and transparency of decision-making. The methods rely on objective data and so treat all investment projects being assessed in a manner that is consistent and fair across project characteristics, locations and time.

The disadvantages people in remote and regional areas face on a range of social and economic indicators, in particular, education, health and employment outcomes, are well documented. The report has cited some of the evidence. The statistics of relative disadvantage reflect in part the high proportions of First Nations people in remote areas. Providing better roads in remote and regional areas can contribute somewhat to improving outcomes as well as supporting government policies in the areas of regional development, development of Northern Australia and Closing the Gap. It is recognised that road improvements can only contribute so much and that upgrading the long lengths of roads in remote and regional areas is costly and has diminishing returns in terms of the benefits generated.

The methods in the report are grouped into 3 themes — social benefits, WEBs and equity. Each theme stands alone and can be implemented without the others. Social benefits and WEBs are economic efficiency benefits that are not counted in traditional CBAs. They also draw attention to possible social and economic impacts.

Social benefits arise from the market imperfections of people under-perceiving the full benefits to themselves and others of additional trips by road. Benefit values per trip have been estimated for trips for education, health and employment purposes. The education benefits are based on the discounted present values of increases in earnings from additional years of education. The health benefits are based on a relationship between visits to general practitioners and years of life. The employment benefits are the taxes paid to governments from additional earnings. Amounts for positive externalities of reduced crime, improved health and social cohesion were added to the education and employment benefit estimates. Social benefits, as defined here, arise only for trips induced by the road improvements being appraised. A methodology was developed for estimating induced trips from road improvements from changes in accessibility measures, CIs, calculated at the SA1 level. It is important to note that the education and health social benefits replace the rule-of-half consumers' surplus change benefits for induced trips, but the employment social benefits are additional.

WEBs arise from imperfections in product and labour markets. The report considered the 3 WEBs estimated for large transport projects in cities and 3 other types of WEB. Agglomeration WEBs are not relevant outside cities. The WEBs arising from labour taxes and output changes in imperfectly competitive markets are likely to be relevant and are straightforward to estimate. The other types of WEBs — change in competition, monopsony labour markets and involuntary unemployment — will be less common and have much greater informational requirements to justify and estimate. Collection of the necessary data is only likely to be worthwhile for assessments of large projects.

The addition of social benefits and WEBs is expected to make only a small difference to benefits in CBAs of remote and regional road projects. Meeting community expectations and government regional policy objectives for road standards in regional areas requires investing in projects with BCRs below one. A survey of literature on distributional equity was undertaken to find a way to justify investing beyond the levels recommended by CBAs and to integrate it with CBA in decision-making. Two problems had to be addressed — (1) disentangling equity in provision of transport from equity in relation to income distribution, and (2) balancing achievement of greater equity against the necessary sacrifice of economic efficiency.

Much discussion of equity in an economic context relates to the distribution of income and wealth. Authors in the transport planning field have drawn on the idea of spheres of justice. Equity in relation to transport can be thought of in terms of accessibility, which is a separate sphere of justice from equity in income and wealth. The question then arises of how much income to sacrifice to reduce inequities of accessibility when the gain in wellbeing for the beneficiaries is less than the combined loss of wellbeing for the general community. Some theories of equity will permit very large sacrifices of wellbeing by the better-off in exchange for a very small gain for the worst-off. They might be practical within a clearly defined urban boundary where improvements can be made for the access-poor at an affordable cost. But moving outside urban boundaries into areas with low population densities, the costs of improving road access rise, benefits fall due to low utilisation of roads, and equitable roads standards need to be adjusted downwards.

The report has proposed a suitable approach by combining elements of the prioritarian and sufficientarian theories of distributive justice. For traffic originating in SA1s with CIs above a threshold level deemed to be ‘sufficient’, no priority is given. Gains to these beneficiaries are given an equity weight of one. Benefits to traffic originating in SA1s with CIs below the sufficiency threshold are prioritised by giving them an equity weight above one, increasing as the CI falls. Suggestions are made for functional forms and ways to calibrate the equity weight function. These equity weights are distinct from utility weights. Utility weights are related to diminishing marginal utility of income. Equity weights represent moral or ethical judgements by decision-makers.

Decisions about whether to apply equity weights, and if so, the functional form and parameter values to apply, need to be made by road agencies at the program level. CBA practitioners should take these as given.

Economists in Australia have been reluctant to apply weights in CBAs. This report seeks to persuade them otherwise by demonstrating that the approach is not ad hoc but has a strong basis in recent academic thinking in the fields of philosophy and transport planning, and that equity weighting brings to decision-making a level of consistency and transparency not achievable with alternatives such as multi-criteria analysis and subjective approaches. Equity weighting is a form of ‘adjusted CBA’ as proposed in the ATAP (2022a T2) CBA guideline. As a safeguard, and in keeping with ATAP (2022a T2), the report recommends that weighted CBA results never be presented without also presenting the unweighted results so decision-makers understand how much economic efficiency is being forgone to meet an equity objective.

Mechanical methods of benefit calculation come with a risk of becoming divorced from reality. Social benefits from improved access to education and healthcare facilities and employment opportunities will not occur where the improved roads do not link with destinations having the necessary facilities or opportunities. Equity weighting might not be appropriate for people who live in remote and regional areas voluntarily for lifestyle reasons. The report therefore recommends that applications of the methods in CBAs be accompanied by a narrative that explains and justifies the applications with reference to the local context.

The methods in this report provide a rigorous, transparent approach to assessing investments to upgrade roads in remote and regional areas that takes account of social, economic and equity impacts and should lead to greater consistency and fairness in decision making.

Appendix A – Supporting literature on social benefits

A.1 Early childhood education (ECE)

The *Dynastic benefits of early childhood education* study (García et al. 2021) found that the cumulative lifetime benefits of attending an ECE program relative to individuals who do not attend amount to USD$61,580 (real 2017 USD, before tax earnings). These benefits arise from the increase in educational attainment, avoided cost of crime, and avoided health costs. This study was undertaken on the outcomes of the Perry Preschool Project in the USA. The study used longitudinal data to identify the benefits delivered by the program. The paper reported that the program had a BCR of 6.1 after accounting for the deadweight losses from collection of the tax required to fund the program.

The *Early childhood education: the long-term benefits study* (Bakken et al., 2017) focused on an ECE program that was run in a midwestern city in the USA called The Opportunity Project, which subsidised disadvantaged children to attend high-quality ECE. The study compared the children's lifetime income, education, and other attainment against similarly disadvantaged children who did not have access to the subsidy. The program specifically targeted children in the 2 years before attending primary education facilities. The majority of the children attending The Opportunity Project performed better academically in all tested areas relative to their peers and were placed in academic advancement programs from first grade onwards. These children also saw higher attendance rates in primary school and fewer disciplinary incidents than their peers.

Quantifying the life-cycle benefits of an influential early childhood program (García et al. 2020) examined the impact of 2 ECE programs aimed at providing high-quality ECE to disadvantaged children in North Carolina, USA. The programs were launched in the 1970s. Participants were followed through to their mid-30s. The programs offered ECE for 9 hours a day, for 50 weeks a year, for 5 years. The programs together were found to have a BCR of 7.3.

Van Huizen et al. (2019) undertook a CBA of implementation of universal 'Early Childhood Education and Care' in Spain for 3-year-olds in the early 1990s. The study found that there are positive effects to the child's lifetime educational attainment and the mother's labour market participation in both the short and long term. The study also estimated the avoided crime and health costs for broader society. The net present value of benefits minus costs (including the cost of the program) was $13,249 per 3-year old child in 1997 dollars and had a BCR of 4.3.

The *Effective pre-school, primary and secondary education project* (EPPSE 3-16+) (UK Department of Education 2015) examined the persistent impacts of attending ECE on lifetime educational attainment. It found that attending any ECE (of low to high quality) has a positive impact on a child's educational attainment through to post-secondary qualifications. Children attending ECE are likely to earn, on average, £27,000 more over their working lives than children who receive little or no pre-school experience, and around £36,000 more taking into account the earnings of other members of their household. The study also found that attending ECE can help to ameliorate some of the disadvantages of growing up in poverty or in households where parents have poor levels of qualifications or provide little intellectual stimulation. These children saw between a one-third to one-half a General Certificate of Secondary Education (GCSE) grade difference above their low socioeconomic status peers who did not attend ECE of any quality.

Early bird catches the worm: the causal impact of pre-school participation and teacher qualifications on year 3 NAPLAN Outcomes (Warren and de New, 2013) found a strong positive relationship between attendance at ECE services and higher NAPLAN (National Assessment Program – Literacy and Numeracy) scores across all domains. This, in turn, was correlated with higher levels of academic attainment and thus higher incomes later in life. The paper also drew a link between the quality of ECE services and the eventual NAPLAN scores, indicating that the higher the ECE quality, the better the child scored in their initial NAPLAN testing.

PwC (2016) modelled the 'Economic impacts of the proposed Child Care Subsidy'. They found that the impact of the Child Care subsidy will result in additional workforce participation by parents (mostly women) growing to 29,000 full-time equivalents in 2050 (about half of which comes from current workers increasing their hours and the other half from new workers joining the workforce). The net fiscal gain to the government was $4.3 billion to 2050 in present value terms discounted at 5% arising from increased tax receipts and lower welfare payments, less the cost of the higher childcare subsidy.

PwC (2019) was commissioned by the Front Project to undertake an economic analysis of ECE in Australia. The analysis focussed on the ECE provided to children in the year before they start school, often referred to as preschool or kindergarten. The benefits identified included

- improved literacy and numeracy for the children attending ECE, which in turn leads to:
    - education cost savings due to lower levels of children repeating a year of school and reduced need for special education programs
    - higher educational achievement resulting in higher lifetime earnings for recipients. The improved cognitive abilities that result from participating in early childhood education can be measured in later school achievement, educational attainment and the resulting impact on employment, earnings, taxation and welfare
- higher levels of workforce participation by parents and carers who choose to participate in additional paid employment while their children are attending ECE, who would not have done so otherwise
- other social benefits and costs flowing from improved education and earnings resulting in cost savings for governments due to a reduction in crime and a reduction in health care costs associated with smoking and obesity.

Using a 3% discount rate, PwC (2019) estimated the present value of benefits at $4,737 million and costs at $2,366 million, giving a net present value of $2,401 million and a BCR of 2.0. This ratio is conservative compared with those found by the other studies reviewed above. The BCR was estimated to be 1.7 at a 4% discount rate and 1.1 at a 7% discount rate. No dollar amounts were provided for costs and benefits at these other discount rates.

By interpolation, the BCR at a 5% discount rate would be 1.527. Assuming all costs are incurred in year one and therefore discounted by one year, the discounted present value of costs becomes,
$2,292 million = $2,366 million × 1.03 / 1.05 at the 5% discount rate. The implied total benefits at a 5% discount rate would be $3,499 million = $2,292 million × 1.527 BCR. The net present value at a 5% discount rate is $1,207 million = $3,499 million – $2,292 million.

As PwC (2019) has been relied upon to obtain the social benefit per trip for ECE in Chapter 4, their CBA results table is reproduced here in full in Table A.1.

A.2 Primary, secondary and tertiary education

Ashenfelter & Rouse (1998), examined education and earnings differences among 700 sets of identical twins living in the US who presumably had the same innate ability levels and were raised in the same family environments. They concluded that each additional year of schooling added an average of 9% to annual income, but the return is slightly greater for low-ability than for high-ability individuals.

Comparable estimates of returns to schooling around the world (Montenegro and Patrinos, 2014) investigated the returns to education using data from 139 economies with 819 household surveys made compatible for analysis and comparison. The average private rate of return from a year of education was 10.1%. By level of education, the returns were 10.6% for primary, 7.6% for secondary, and 15.2% for tertiary (p. 7). Private returns were defined as the undiscounted lifetime amount an individual will earn after tax, less costs they incur for attending school (fees, tuition, forgone earnings) above a comparable group with less schooling. For Australia, the average return for all levels was 11.8% (p. 20).

Table A.1 Results of cost–benefit analysis of early childhood education (3% discount rate)

	Group affected	Present value ($ millions)
Cost of early childhood education		
Cost to government	Government	$1,835
Cost to households	Parents/carers	$501
Total costs		**$2,336**
Benefits of early childhood education		
Parental earnings benefits	Parents/carers	$1,463
Taxation benefits of additional parental income	Government	$313
Higher earnings for children over lifetime	Children	$1,064
Additional productivity benefits from children	Employers	$319
Reduced expenditure on special education	Government	$3
Reduced expenditure on school repetition	Government	$11
Reduced health expenditure	Government	$605
Reduced crime-related expenditure	Government	$522
Reduced welfare expenditure	Government	$67
Reduction in welfare payments to individuals	Children	–$67
Other costs – additional schooling costs	Government	–$58
Total benefits		$4,737
Net present value		$2,401
Benefit–cost ratio		2.0

Source: PwC (2019, p. 6).

In the UK, *The economic value of key intermediate qualifications: estimating the returns and lifetime productivity gains to GCSEs, A levels and apprenticeships* (Hayward et al. 2014) found that

- compared to people with no qualifications at all, the marginal lifetime productivity returns to 2 or more A levels were around £441,000 for men and £354,000 for women (p. 28)
- individuals achieving 5 or more good GCSEs (including English and maths) as their highest qualification have a lifetime productivity gain worth around £100,000 compared to those with below level 2 or no qualifications. Restricting the comparison group to just those with no qualifications boosts the returns to £283,000 for men and £232,000 for women (p. 48).

Measuring heterogeneity in the returns to education in Norway using educational reforms (Aakvik et al. 2010) found that upper secondary school generates a 24% return for the 3 years of education. Two to 3 years of vocational training gives a much lower return of about 8.6%, and one year of vocational training yields a return of about 1%. The return to a master's degree is 45% relative to that of compulsory school (pp. 30-1).

Boarini and Strauss (2010) estimated internal rates of return for OECD countries from tertiary education. The internal rate of return is the discount rate that equates the lifetime benefits from education with its costs. The cross-country average was 8.5% with a range from 4% to 14%. For Australia, the rates of return were around 10%.

Leigh & Ryan (2008), *Estimating returns to education using different natural experiment techniques* used instrumental variables to correct for ability bias. Using naïve ordinary least squares regression and data from the Household, Income and Labour Dynamics in Australia (HILDA) survey, an additional year of schooling increased annual pre-tax income by 13%. Different instrumental variable approaches reduced this to 8% or 12%. Their preferred estimate of the ability-adjusted rate of return to schooling in Australia was 10%. At this rate, the discounted present value of an additional year of schooling, taking into account the forgone earnings while at school, was $56,440 at a 3% discount rate and $37,778 at a 5% discount rate in 2003 dollars.

Leigh (2008), *Returns to education in Australia*, covered both secondary and tertiary education using HILDA data. Ordinary least squares regression results were adjusted downward for a 10% ability bias (the percentage return multiplied by 0.9). Leigh found that annual earnings were higher by 20% for completing Grade 10, 30% for Grade 12, 15% for each year of a bachelor degree and 13% for each year of a masters or doctoral degree. Results were also presented for hourly earnings as a measure of productivity, and probability of positive earnings as a measure of participation. The annual earnings results combine the 2 effects. For high schools, slightly less than half the gains were due to increased productivity with the rest being due to higher levels of participation. For vocational training, about one-third of the gains were from productivity and two-thirds from greater participation. For universities, most of the gains were from productivity.

The case for investing in public schools (Littleton et al. 2023) examined data from the 2021 Census for education level, earnings and age bracket. They found a 21.4% wage premium for finishing Grade 12 without going on to further study, earning $414,000 (not discounted) more over their lifetime than a person who had not completed Grade 12.[35]

In *Counting the costs of lost opportunity in Australian education*, Lamb & Huo (2017) used 2011 Census data, to estimate the difference in lifetime earnings between people who did and did not complete Year 12 or equivalent qualifications. They also estimated a broader range of costs related to the tax and welfare payments, crime and law enforcement, and public health, making a distinction between impacts on governments, termed the 'fiscal' cost, and impacts on society as a whole, including the individual concerned. Table A.2 summarises their findings, expressed as lifetime present values.

Table A.2 Lifetime cost per person of not completing year 12 or equivalent education

($'000, 2014 prices, present values at a 3.5% discount rate)

	Gross income	Tax	Welfare	Crime	Health	Marginal excess tax burden	Total
Fiscal cost		230.4	96.7	2.3	5.2		334.6
Social cost	573.1			17.9		25.2	616.2

Note: The marginal excess tax burden is the cost of the distortion caused by raising taxes to pay for the higher fiscal (government) costs of the welfare payments, crime and health impacts shown in the other columns of the table.

Source: Lamb & Huo (2017), p. 47.

Chapman & Lounkaew (2015) estimated the externalities from education. They defined 'externalities' as covering both:

- 'non-pecuniary' externalities including reduced crime, improved health, more informed political debate, and strengthening of civil society
- 'pecuniary' or 'fiscal' externalities of additional tax receipts.

From 2008 HILDA survey data, Chapman & Lounkaew econometrically estimated earnings as a function of age for people who had completed grade 12 and university. Lifetime taxes were then estimated to obtain the fiscal externality component. They assumed that 40% to 60% of this was attributable to education, the rest being due to signalling or screening (explained below), and made a 10% downward adjustment for ability consistent with Leigh (2008 & 2024). Non-pecuniary externalities were assumed to be 30% of the private return from higher education based on OECD values from a large international survey in McMahon (2004). For a 4-year degree, the combined fiscal and non-pecuniary externalities were estimated to be $10,635 to $15,952 per year of higher education in 2014 prices, depending on whether signalling was assumed to

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35 Using the methodology of the present report, described in Section 4.3.2 above, with a zero discount rate, a person with Grade 12 as their highest education level would earn $483,000 more over their lifetime than a person with only Grade 11 and $631,000 more than a person with only Grade 10.

represent 40% or 60% of the returns from higher education. No allowance was made for the costs to the government of funding universities.

Leigh (2024) is an update of Leigh (2008), again undertaken by regression analysis of HILDA data. As in Leigh (2008), results were adjusted downward to compensate for a 10% upwards ability bias. It was concluded that there is little evidence that returns to education in Australia have changed during the 2000s and 2010s. As the Leigh (2024) estimates were used estimate education benefits per trip in Chapter 4, they are reproduced in Table A.3. The Leigh (2008) estimates are included for comparison. The increase in annual earnings from an additional year of education averages out at 13%, which is consistent with other estimates. The Grade 12 year has a particularly high return, at 27% or 30%.

Table A.3 Per year returns to education from Leigh (2008) and (2024)

(percent increase in annual earnings from an additional year of education)

	2008	2024
High school: Sample is respondents with no post-school qualifications		
Grade 10	20	10 (ns)
Grade 11	7 (ns)	7
Grade 12	30	27
Vocational training: Sample is respondents with 11 or fewer years of high school		
Certificate Level III or IV	19	16
Diploma or Advanced diploma	10	19
Post-school qualifications: Sample is respondents with 12 years of high school		
Certificate Level III or IV	–3 (ns)	4 (ns)
Diploma or advanced diploma	8	6
Bachelor degree	15	14
Graduate diploma or graduate certificate	10	10
Masters or doctorate	13	14
Column average	13	13

Notes: Percentage annual returns were calculated as $0.9(e^{\beta} - 1)/y$ where 0.9 is an adjustment for an assumed 10% upward ability bias, β is the regression coefficient, and y is the number of years of full-time study assumed for each qualification. The numbers of years were one year for certificate III/IV, 2 years for a diploma or advanced diploma, 3 years for a bachelor degree, 4 years for a graduate diploma or graduate certificate, and 5 years for a masters or doctorate. 'ns' denotes results that were not statistically significant at 1% level. The column average includes 'ns' results.

Sources: Leigh (2008) and (2024).

It was noted in Section 4.3.2 that the literature is divided on the significance of signalling, that is, the relationship between education and earnings may be due in part to the way educational qualifications send a signal to potential employers that a job applicant will be a good worker. Leigh (2024) found some evidence in support of the theory in his finding that the per-year returns from completing year 11 are smaller than the per-year returns from completing year 12. But Leigh went on to cite research that rejects the pure signalling theory for university education. Australian students who drop out of university tend to earn more than those who do not commence a degree, and many university dropouts report that what they learned at university helped them in the labour market.

Chapman & Lounkaew (2015), on the other hand, citing different research, consider that some 40% to 60% of the earnings premium from education are pure human capital effects with the remainder from signalling. One piece of Australian evidence they note is that bachelor degree completion premiums in earnings are about 8%

in the first year after completing the degree, which could be attributed to screening. The earnings premium rises to 12% or 13% in the third year, which would reflect skills, because employers have, by then, observed how the graduates perform. It can be inferred that screening accounts for around 67% = 8% / 12% of the earnings premium leaving 33% as the pure human capital effect.

A.3 Health care

Improving access to healthcare facilities can lead people to seek earlier and more frequent medical advice and assistance to address health issues, which can improve health outcomes and save healthcare costs in the long term. Our literature survey only uncovered one example of a dollar value of the benefits to society of an additional trip to a healthcare facility that could be applied in CBAs, that in, Godavarthy et al. (2014). However, there is considerable literature supporting the underlying idea.

Baade et al. (2011) provided evidence of shorter survival for people with rectal cancer who live relatively far from radiotherapy facilities. They found that on average there was a 6% increase in mortality risk (95% confidence interval, 3%–8%; $P < 0.001$) for each 100km increment in distance from the nearest radiotherapy facility. Shared frailty models showed that this association persisted after adjusting for the correlation between individual cancer patients living in the same remoteness area level and socioeconomic status categories.

Kelly et al. (2016) undertook a systematic review of studies of the relationship between travel time or distance to healthcare for adults in global north countries and health outcomes. 108 studies met their inclusion criteria. 77% of these studies identified evidence of a distance decay association, whereby patients living further from healthcare facilities they needed to attend had worse health outcomes (eg, survival rates, length of stay in hospital and non-attendance at follow-up) than those who lived closer.

Mseke et al. (2024) reviewed literature from US, UK, Canada and Australia on the impact of travel distance and time on access to healthcare. Distance decay, defined as a reduction in health service access with an increase in distance or travel time, is widely recognised and reported to affect the utilisation of both primary and specialist healthcare services (p. 2). Evidence of distance or travel time decay was identified in 113 (84%) of the studies included. The shortest distance found to impact healthcare access was 10 miles (16km) recorded in 2 US studies. The shortest travel time at which distance decay become apparent was 30 minutes. Mseke et al. (2024) mentioned road quality as one consideration in healthcare access.

A US study, Rose et al. (2019), examined the impact of regular and irregular primary care visits on patient outcomes including emergency department presentations, Medicare expenditure and benefits for the beneficiary. Rose et al. (2019) found that regular visits, compared to irregular visits, are associated with lower rates of emergency department visits (1.31 vs 1.70), reduced rates of hospitalisations (0.57 vs 0.69) and lower Medicare expenditures ($17,430 vs $20,731).

Godavarthy et al. (2014) estimated the benefits of routine care or non-emergency medical transportation (NEMT) trips, by averting more costly care and improving quality of life using research by Hughes-Cromwick et al. (2005). Their work applied to trips in rural and small-urban America.

> Hughes-Cromwick et al. (2005) estimated the number of health care visits required for various chronic diseases by examining the disease management literature. They determined the number of trips a patient with a specific disease would be required to take per year so that their condition would be considered well-managed. Then, they determined the characteristics of a poorly managed patient so they could estimate the benefit of moving from poorly to well-managed care. Having well-managed care means that complications are minimized, costly care is avoided, and quality of life is enhanced. Poorly managed care could be a result of patient noncompliance, but lack of transportation can also play a significant role.
>
> Their analysis included a noncompliance factor, which accounts for providers who do not adhere to standards of well-managed care, patients who do not adhere to treatment, and patients whose disease is considered uncontrollable, despite all best efforts. Their study assumed different rates of compliance for each condition, based on previous research.

Impacts of a treatment on quality of life can be measured using the Quality Adjusted Life-Year (QALY) measure. QALY was developed in an attempt to combine quality of life and length of life into a single measure and is often used to compare the cost effectiveness of treatments (Prieto and Sacristan 2003). It assumes that one year of life lived in perfect health is equal to one QALY, and one year of life lived with less than perfect health is worth less than one QALY. Hughes-Cromwick et al. (2005) cited research from health economics showing that investments that provide one additional QALY are valued at $50,000. Therefore, they deemed effective any investment that provides one QALY and costs less than $50,000.

[…]

The benefit from providing a trip for medical purposes is the difference between well-managed and poorly-managed care, which can include a reduction in more costly care and improved quality of life. Calculations from a spreadsheet tool developed by Hughes-Cromwick et al. (2005) were used to estimate this benefit. Assumptions [were made] regarding the percentage of adult users of NEMT services who have different chronic conditions or require preventive care, as well as the number of office visits required for each[…]. These estimates are national norms identified by Hughes-Cromwick et al. (2005). The benefits of NEMT trips are calculated as the cost difference between well-managed and poorly-managed care, plus improvements in quality of life, minus costs of additional medical treatment incurred, divided by the number of trips required. Using the tool developed by Hughes-Cromwick et al. (2005), results in a net benefit of $713 per round trip, or $357 per one-way trip. Therefore, this is assumed to be the cost of foregone medical trips. The total number of foregone medical trips was multiplied by $357 to determine the total cost of foregone medical trips. (Godavarthy et al. 2014, pp. 6 and 25)

Appendix B – Worked examples

This appendix presents 2 worked examples to illustrate how to apply the methods of Chapters 5 and 7. They are based on actual CBAs with assumptions made where required information was not in the CBA documentation available. The benefit estimates are partial in that they only estimate benefits associated with one SA1 in each case. A full CBA would estimate benefits associated with all SA1s that are origins for car traffic benefitting from the upgrades and for which CIs would be affected.

B.1 Great Northern Highway, Western Australia

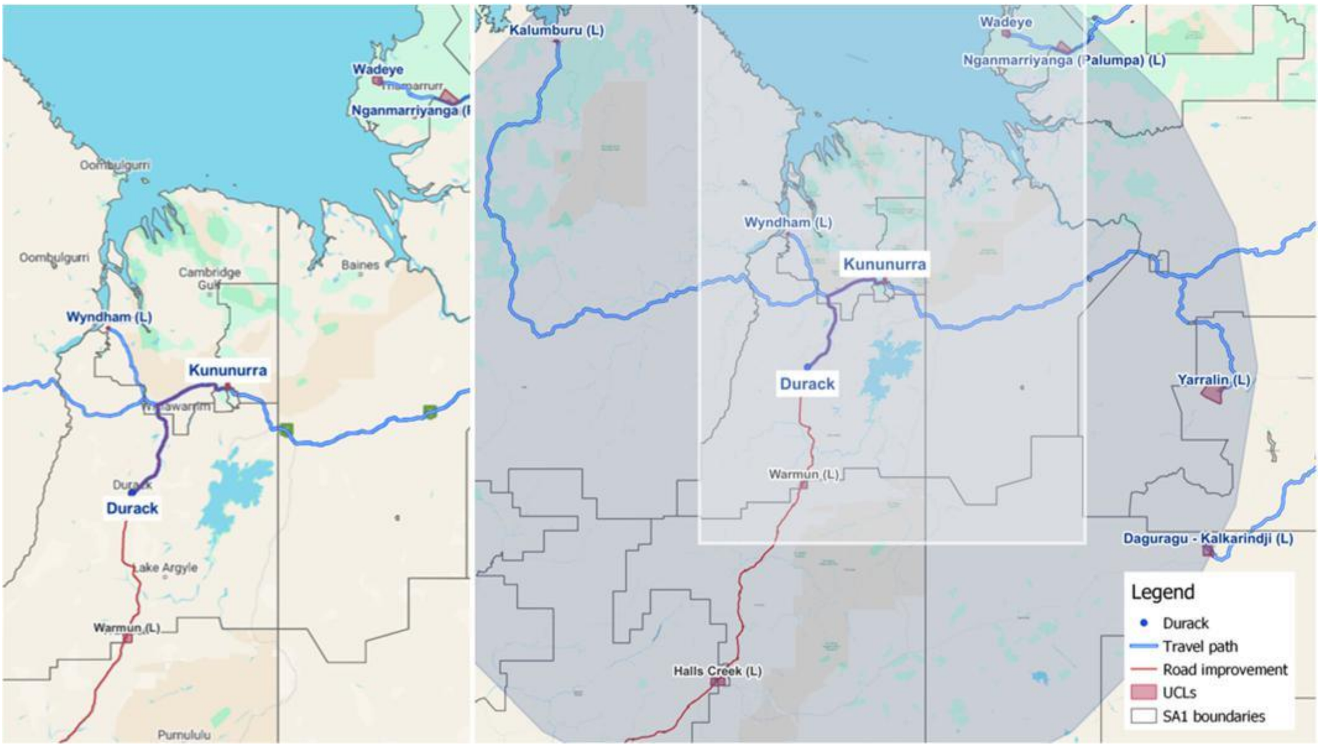
Project description

The first worked example is taken from a rapid economic appraisal for potential improvements to the Great Northern Highway network between Broome and Kununurra in Western Australia. The Great Northern Highway is a key transportation route that runs north from Perth to the town of Wyndham in the Kimberley region of Western Australia. It is part of the designated National Land Transport Network. At the Wyndham turnoff, the highway connects to the Victoria Highway before continuing onward to the border with the Northern Territory.

The project comprises road improvements over a distance of 39km allowing average speed to increase from 60km/h to 65km/h.

Durack is the origin SA1 and will be referred to as such rather than by its code, 51001126511. (SA1s do not have names, only codes.) The road improvements will save 3 minutes travel time per light vehicle between Durack and UCLs accessed by the Great Northern Highway northbound. Three UCLs enter into the CI for Durack — Kununurra and Wyndham to the north, and Warmun to the south. Figure B.1 maps the locations of Durack and the surrounding UCLs and roads.

Figure B.1 Durack and surrounding UCLs and roads



Source: KPMG

Base-case and project-case connectivity indexes

Table B1.1 computes the 3 CIs for the Durack SA1 using base-case travel times and project-case travel times, then shows the change in the CIs from the base case to the project case. As expected, the CIs are slightly higher in the project case. From Section 3.3.3

$$CI_i = \sum_j e^{\lambda\, t_{ij}} P_j^{\mu}$$

where, for SA1 *i*

- t_{ij} is travel time in minutes from the centroid of SA1 *i* to the centroid of UCL *j*
- λ is –0.06 for employment trips, –0.05 for education trips and –0.04 for health-related trips
- P_j is the population of UCL *j*
- μ is 0.8 for employment trips, and 0.6 for education trips and health-related trips.

Table B1.1 Connectivity index calculations: Durack SA1

UCL	Travel times (minutes)	UCL populations	CI Education	CI Health	CI Employment
	(1)	(2)	exp[-0.05×(1)]×(2)$^{0.6}$	exp[-0.04×(1)]×(2)$^{0.6}$	exp[-0.06×(1)]×(2)$^{0.8}$
Base case					
Kununurra	105	4,515	0.818	2.338	1.541
Wyndham	91	745	0.559	1.388	0.844
Warmun	50	457	3.238	5.338	6.684
CI base case (total)			**4.614**	**9.064**	**9.069**
Project case					
Kununurra	102	4,515	0.950	2.636	1.844
Wyndham	88	745	0.649	1.565	1.011
Warmun	50	457	3.238	5.338	6.684
CI project case (total)			**4.837**	**9.539**	**9.539**
Change					
Change in CI			**0.029**	**0.084**	**0.032**

Induced trips and social benefits

Table B1.2 starts with the changes in the CIs from Table B1.1 and estimates induced trips per day originating in the SA1 from the formula given in Section 3.5

$$Induced\ trips\ per\ day = \Delta CI \times factor \times relevant\ population$$

The number of induced trips per day is then multiplied by 365 to obtain trips year. Trips per year are multiplied by the benefit per trip values from Section 3.6 to obtain the total social benefit for each trip purpose.

Benefit values at the 5% discount rate have been used for education benefits. As the social benefit estimates are so small, it may not be worth the trouble of changing them when undertaking sensitivity tests at different discount rates. The total social benefit for the Durack SA1 is $343 per annum. However, as there no tertiary education facilities in the relevant UCLs, the $54.50 social benefit for tertiary education will not be realised. The final benefit estimate is therefore $289.35 = $343.85 – $54.50.

The social benefit estimate is extremely small but the methodology applied to other projects and to multiple SA1s that benefit from the same project might give rise to a material result.

Table B1.2 Estimation of social benefit: Durack SA1

Trip purpose	Increase in CI	Factor x 1m	Relevant population	Induced trips per day all persons	Induced trips per year all persons	Benefit per trip	Benefit per year
	(1)	(2)	(3)	(4)=(1) × (2) × (3) / 1m	(5)=(4) × 365	(6)	(7)=(5)×(6)
Education EC	0.223	103.69	23	0.000531	0.1940	$35	$6.79
Education P&S	0.223	15.96	30	0.000107	0.0389	$349	$13.59
Education Tert.	0.223	64.91	29	0.000419	0.1531	$356	$54.50
Health	0.475	1.64	306	0.000238	0.0870	$3,000	$261.03
Employment	0.470	1.88	214	0.000189	0.0691	$115	$7.94
Total				**0.001485**	**0.5421**		**$343.85**

Note: EC = early childhood, P&S = primary and secondary, Tert. = tertiary

Social benefits from reduction in lost trips due to flooding

The project will reduce the average annual time of closure (AATOC) due to flooding from 120 to 48 hours per year for northbound trips out of Durack. Dividing by 24, the AATOC in days reduces from 5 to 2.

A reduction in trips cancelled due to flooding can be valued using the social benefit values. Table B1.3 estimates the share of trips originating in Durack to each of the 3 UCL destinations by applying the logit formula for trips per person to the base-case CI components in Table B1.1. The formula is

$$\rho_{ik} = \frac{e^{\lambda\, t_{ik}} P_k^{\mu}}{\sum_j e^{\lambda\, t_{ij}} P_j^{\mu}} = \frac{e^{\lambda\, t_{ik}} P_k^{\mu}}{CI_i}$$

where ρ_{ik} is the proportion of trips originating in SA1 *i* that have UCL *k* as their destination. The share of northbound trips is the sum of shares to Kununurra and Warmun.

Table B1.3 Share of northbound trips calculation

	All trips shares			Northbound trips shares		
	Education	Health	Employment	Education	Health	Employment
Kununurra	17.7%	25.8%	17.0%	17.7%	25.8%	17.0%
Wyndham	12.1%	15.3%	9.3%	12.1%	15.3%	9.3%
Warmun	70.2%	58.9%	73.7%	0.0%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	**29.8%**	**41.1%**	**26.3%**

In Table B1.4, the number of eastbound trips is obtained by applying the eastbound shares in Table B1.3 to base-case trips per person per day for each trip-purpose obtained from the data files produced by KPMG for the regression analysis described in Chapter 3 and Appendix C. Actual trip numbers should be used if available instead of estimates made using the logit model. The reduction in lost trips per year is the base-case trips per day rate multiplied by the reduction in days lost per year and the proportion of trips that are cancelled, assumed to be 10%, shown in Table B1.4. For all trip purposes combined, the reduction in lost trips is 11 trips per year.

Table B1.4 Estimation of reduction in lost trips per year due to flooding: Durack SA1

Trip purpose	Northbound share of trips	Total trips per day	Northbound trips per day	Days lost per year base case	Days lost per year project case	Proportion not travelling	Reduction in lost trips per year
	(1)	(2)	(3)=(1) × (2)	(4)	(5)	(6)	(7)=(3) × [(4)–(5)] × (6)
Education EC	29.8%	6.090	1.817	5	2	10%	0.545
Education P&S	29.8%	22.462	6.702	5	2	10%	2.011
Education Tert.	29.8%	0.000	0.000	5	2	10%	0.000
Health	41.1%	3.361	1.382	5	2	10%	0.414
Employment	26.3%	103.037	27.095	5	2	10%	8.128
Total		**134.950**	**36.996**				**11.099**

Table B1.5 multiplies the reduction in lost trips per by the corresponding social benefit per trip values from Section 3.6 to obtain the benefit per year. The total annual benefit is $2,899.

Table B1.5 Estimation of social benefits per year for reduction in lost trips: Durack SA1

Trip purpose	Reduction in lost trips per year	Benefit per trip	Benefit
	(1)	(2)	(3)=(1) × (2)
Education EC	0.545	$35	$19.08
Education P&S	2.011	$349	$701.71
Education Tert.	0.000	$356	$0.00
Health	0.414	$3,000	$1,243.47
Employment	8.128	$115	$934.77
Total	**11.099**		**$2,899.03**

Rule-of-half benefit for induced employment trips

For northbound trips, the 3-minute saving in travel time is worth $1.48 = 0.05 hours × $35.59 per hour value of commuter travel time savings from ATAP (2025). The vehicle operating cost saving for a car is $0.57 = 39km × $0.0145 per kilometre arising from the higher speed and reduced average road roughness from 3.5 to 2.5m/km international roughness index (IRI). The generalised cost per round trip falls by $4.69 = ($1.48 + $0.57) × 2. The annual benefit to the existing 37 northbound trips per day (from Table B1.4) for all 3 trip purposes for the base case is $63,358 = 36.996 × 365 × $4.69.

As pointed in out in Chapter 4, social benefits for education and health trips already include rule-of-half benefits because these social benefits comprise both perceived (rule-of-half) and unperceived benefits. Rule-of-half benefits are additional to the employment social benefit because the social benefit comprises only the unperceived benefits of tax and externality impacts. From Table B4.3, the number of induced employment trips is 0.0691 trips per year. The rule-of-half benefit is $0.16 = 0.0691 × $4.69 / 2.

Equity weighting

To illustrate the calculation of the equity weight, it is assumed that the employment CI is being used to set the equity weights, the threshold below which weights exceed one, *T*, is 3,000, and the maximum allowable weight, w_{max}, is 3.0.

For the isoelastic function, an elasticity of 0.5 is assumed, which means that the weights will be restricted to 3.0 for CIs below 2.4315. The CIs for the Durack SA1 are at the extreme low end of the scale. If the equity weighting scheme was implemented, it is quite likely that the CI for Durack would be below the level at which the maximum equity weight applies (A_m).

The weight for benefits to trips originating in the Durack SA1 with a base-case employment CI of 9.069 from Table B1.1 would be

$$w_i = \left(\frac{ln\ T}{ln\ A_i}\right)^{\eta} = \left(\frac{ln\ 3000}{ln\ 9.069}\right)^{0.5} = 1.906$$

The linear weighting function with the same threshold and maximum weight values and that produced the same weight would be a straight line between the points (*ln* 3,000, 1) and (*ln* 0.00812, 3.0) (an A_m value of 0.00812), would have a slope, *b*, of 0.1561 and intercept, *a*, of 2.2497.

$$w_i = a - b \cdot ln\ A_i = 2.2497 - 0.1561 \times\ ln\ 9.069 = 1.906$$

All project benefits accruing to trips originating in the Durack SA1 would be multiplied by an equity weight of 1.906.

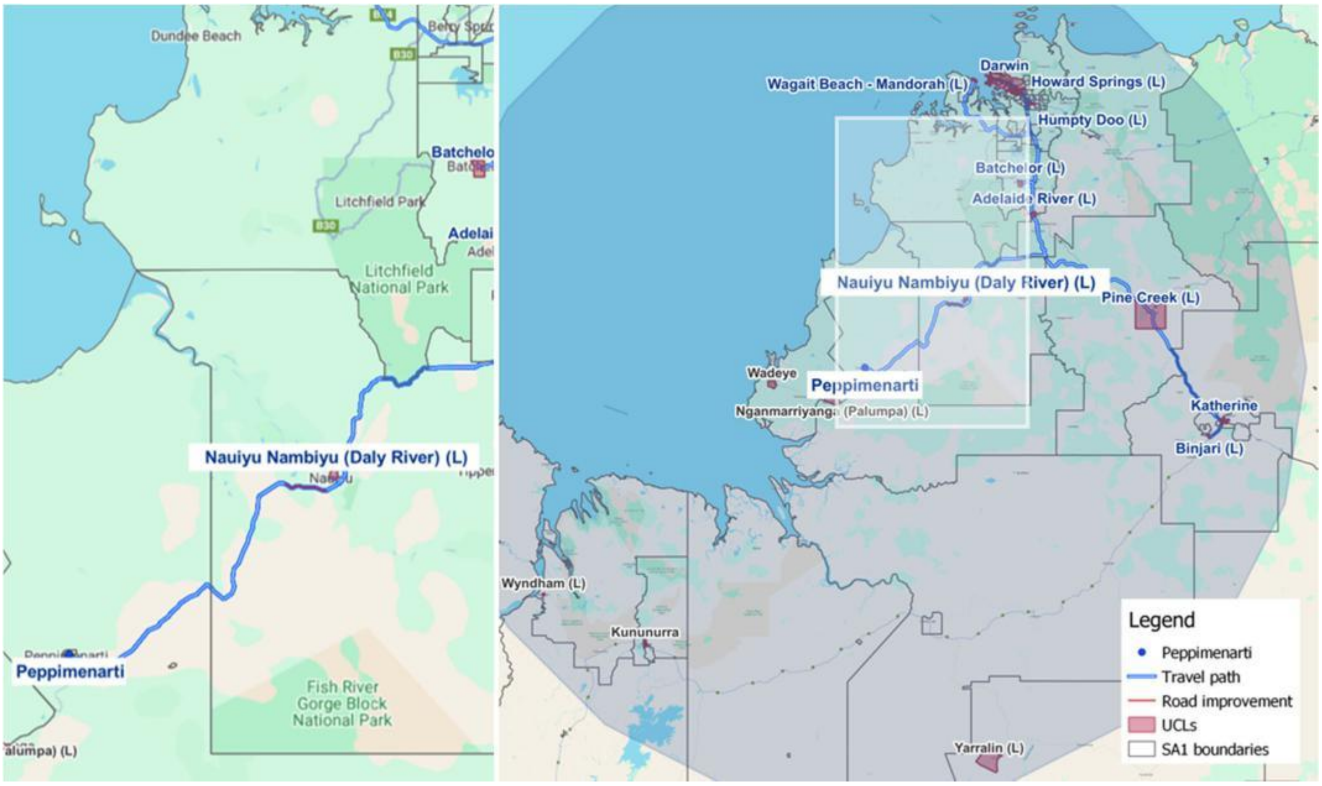
B.2 Port Keats Road, Northern Territory

Project description

The second worked example is based on a technical note for a rapid CBA of potential improvements to Port Keats Road and Saddle Rail Creek Bridge between Yellow Creek Crossing and Saddle Rail Creek in the Northern Territory. Port Keats Road runs from Nauiyu (Daly River) about 220km south of Darwin west to the town of Wadeye. It provides access to communities, farms and mining operations to the west of the Daly River. The worked example is undertaken for the Peppiminarti SA1, code 70203105805, located close to Port Keats Road roughly midway between Nauiyu and Wadeye.

The project comprises road improvements over a distance of 46.22km allowing average speed to increase from 80km/h to 110km/h and saving 9.4541 minutes of travel time. Seven UCLs enter into the CI for Peppiminarti, listed in Table B2.1. The project occurs on the Port Keats road to the east of Peppiminarti so trips from Peppiminarti to the Wadeye and Nganmarriyang UCLs to the west do not receive any benefits. Figure B.2 maps the locations of Peppimarti and the surrounding UCLs and roads.

Figure B.2 Peppiminarti and surrounding UCLs and roads



Source: KPMG

Base-case and project-case connectivity indexes

Table B2.1 computes the 3 CIs for the Peppiminarti SA1 using base-case travel times and project-case travel times, then shows the change in the CIs from the base case to the project case. As expected, the CIs are slightly higher in the project case.

Table B2.1 Connectivity index calculations: Peppiminarti SA1

UCL	Travel times (minutes)	UCL populations	CI Education	CI Health	CI Employment
	(1)	(2)	$\exp[-0.05\times(1)]\times(2)^{0.6}$	$\exp[-0.04\times(1)]\times(2)^{0.6}$	$\exp[-0.06\times(1)]\times(2)^{0.8}$
Base case					
Pine Creek	278.167	318	28.9e-6	466.9e-6	5.7e-6
Wadeye	111.100	1924	0.361	1.098	0.540
Nauiyu Nambiyu (Daly River)	130.833	350	0.048	0.179	0.042
Batchelor	270.300	371	47.0e-6	701.5e-6	10.3e-6
Adelaide River	245.667	243	125.0e-6	1.5e-6	32.1e-6
Nganmarriyanga (Palumpa)	66.250	364	1.253	2.431	2.102
Timber Creek	458.367	278	3.3e-6	319.0e-6	102.6e-6
CI base case (total)			**1.663**	**3.711**	**2.684**
Project case					
Pine Creek (L)	268.713	318	46.4e-6	681.5e-6	10.0e-6
Wadeye	111.100	1924	0.361	1.098	0.540
Nauiyu Nambiyu (Daly River)	121.379	350	0.078	0.262	0.075
Batchelor	260.846	371	75.4e-6	1.0e-6	18.1e-6
Adelaide River	236.213	243	200.5e-6	2.1e-6	56.7e-6
Nganmarriyanga (Palumpa)	66.250	364	1.253	2.431	2.102
Timber Creek	448.913	278	5.2e-6	465.6e-6	181.0e-6
CI project case (total)			**1.693**	**3.794**	**2.716**
Change					
Change in CI			**0.223**	**0.475**	**0.470**

Induced trips and social benefits

Table B2.2 starts with the changes in the CIs from Table B2.1 and estimates induced trips per day originating in the SA1 from the formula given in Section 3.5

$$Induced\ trips\ per\ day = \Delta CI \times factor \times relevant\ population$$

The number of induced trips per day is then multiplied by 365 to obtain trips year. Trips per year are multiplied by the benefit per trip parameters from Section 3.6 to obtain the total social benefit for each trip purpose.

Benefit values at the 5% discount rate have been used for education benefits. As the social benefit estimates are so small, it may not be worth the trouble of changing them when undertaking sensitivity tests at different discount rates. The total social benefit for the Peppiminarti SA1 is $41 per annum. However, as there no tertiary education facilities in the relevant UCLs, the $9.43 social benefit for tertiary education will not be realised. The final benefit estimate is therefore $31.73 = $41.16 – $9.43.

The social benefit estimate is extremely small but the methodology applied to other projects and to multiple SA1s that benefit from the same project might give rise to a material result.

Table B2.2 Estimation of induced trips and social benefits per year: Peppiminarti SA1

Trip purpose	Increase in CI	Factor x 1m	Relevant population	Induced trips per day all persons	Induced trips per year all persons	Benefit per trip	Benefit per year
	(1)	(2)	(3)	(4)=(1) × (2) × (3) / 1m	(5)=(4) × 365	(6)	(7)=(5)×(6)
Education EC	0.029	103.69	48	0.000146	0.0534	$35	$1.87
Education P&S	0.029	15.96	17	0.000008	0.0029	$349	$1.02
Education Tert.	0.029	64.91	38	0.000073	0.0265	$356	$9.43
Health	0.084	1.64	190	0.000026	0.0095	$3,000	$28.53
Employment	0.032	1.88	123	0.000007	0.0027	$115	$0.31
Total				**0.000260**	**0.0951**		**$41.16**

Note: EC = early childhood, P&S = primary and secondary, Tert. = tertiary

Social benefits from reduction in lost trips due to flooding

The project will reduce the average annual time of closure (AATOC) due to flooding from 162 to 0 days per year for eastbound trips out of Peppiminarti.

A reduction in trips cancelled due to flooding can be valued using the social benefit values. Table B2.3 estimates the share of eastbound trips originating in Peppiminarti to each of the 7 UCL destinations by applying the logit formula for trips per person to the base-case CI components in Table B2.1. The share of eastbound trips is the sum of shares to the 5 UCLs excluding Wadeye and Nganmarriyanga.

Table B2.3 Share of eastbound trips calculation

	All trips shares			Eastbound trips shares		
	Education	Health	Employment	Education	Health	Employment
Pine Creek	0.00%	0.01%	0.00%	0.00%	0.01%	0.00%
Wadeye	21.73%	29.58%	20.12%	0.00%	0.00%	0.00%
Nauiyu Nambiyu (Daly River)	2.91%	4.83%	1.57%	2.91%	4.83%	1.57%
Batchelor	0.00%	0.02%	0.00%	0.00%	0.02%	0.00%
Adelaide River	0.01%	0.04%	0.00%	0.01%	0.04%	0.00%
Nganmarriyanga (Palumpa)	75.35%	65.51%	78.31%	0.00%	0.00%	0.00%
Timber Creek	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	100.00%	100.00%	100.00%	**2.93%**	**4.90%**	**1.58%**

In Table B2.4, the number of eastbound trips is obtained by applying the eastbound shares in Table B2.3 to base-case trips per person per day for each trip-purpose obtained from the data files produced by KPMG for the regression analysis described in Chapter 3 and Appendix C. Actual trip numbers should be used if available instead of estimates made using the logit model. The reduction in lost trips per year is the base-case trips per day rate multiplied by the reduction in days lost per year and the proportion of trips that are cancelled, assumed to be 95%, shown in Table B2.4. For all trip purposes combined, the reduction in lost trips is 162 trips per year.

Table B2.4 Estimation of reduction in lost trips per year due to flooding: Peppiminarti SA1

Trip purpose	Eastbound share of trips	Total trips per day	Eastbound trips per day	Days lost per year base case	Days lost per year project case	Proportion not travelling	Reduction in lost trips per year
	(1)	(2)	(3)=(1) × (2)	(4)	(5)	(6)	(7)=(3) × [(4)–(5)] × (6)
Education EC	2.9%	4.255	0.124	162	0	95%	19.157
Education P&S	2.9%	10.452	0.306	162	0	95%	47.060
Education Tert.	2.9%	0.000	0.000	162	0	95%	0.000
Health	4.9%	1.368	0.067	162	0	95%	10.320
Employment	1.6%	35.306	0.557	162	0	95%	85.674
Total		51.379	1.054				**162.211**

Table B2.5 multiplies the reduction in lost trips per year for each trip purpose by the corresponding social benefit values from Section 3.6 to obtain the benefit per year. The total annual benefit is $57,906. It is likely that, in the base case, some patients requiring emergency care would be transported by air. The cost saved in the project case would be an additional benefit from ending road closures due to flooding.

Table B2.5 Estimation of social benefits per year for reduction in lost trips: Peppiminarti SA1

Trip purpose	Reduction in lost trips per year	Benefit per trip	Benefit
	(1)	(2)	(3)=(1) × (2)
Education EC	19.157	$35	$670.50
Education P&S	47.060	$349	$16,424.03
Education Tert.	0.000	$356	$0.00
Health	10.320	$3,000	$30,959.08
Employment	85.674	$115	$9,852.49
Total	**162.211**		**$57,906.09**

Rule-of-half benefit for induced employment trips

For eastbound trips, the 9.454-minute saving in travel time is worth $5.61 = 0.1576 hours × $35.59 per hour value of commuter travel time savings from ATAP (2025). The vehicle operating cost saving for a car is $1.53 = 46.22km × $0.0332 per kilometre arising from the higher speed and reduced average road roughness from 5.8 to 2.0 m/km international roughness index (IRI). The generalised cost per round trip falls by $14.28 = ($5.61 + $1.53) × 2. The annual benefit to the existing 1.054 eastbound trips per day (from Table B2.4) for all 3 trip purposes for the base case is $5,495 = 1.054 × 365 × $14.28.

As pointed in out in Chapter 4, social benefits for education and health trips already include rule-of-half benefits because these social benefits comprise both perceived (rule-of-half) and unperceived benefits. Rule-of-half benefits are additional to the employment social benefit because the social benefit comprises only the unperceived benefits of tax and externality impacts. From Table B2.2, the number of induced employment trips is 0.0027 trips per year. The rule-of-half benefit is \$0.02 = 0.0027 × \$14.28 / 2.

Equity weighting

To illustrate the calculation of the equity weight it is assumed that the employment CI is being used to set the equity weights, the threshold below which weights exceed one, T, is 3,000 and the maximum allowable weight, w_{max}, is 3.0.

For the isoelastic function, an elasticity of 0.5 is assumed, which means that the weights will only be restricted to 3.0 for CIs below 2.4315. The CIs for the Peppiminarti SA1 are at the extreme low end of the scale. If the equity weighting scheme was implemented, it is quite likely that the CI for Peppiminarti would be below the level at which the maximum equity weight applies (A_m).

The weight for benefits to trips originating in the Peppiminarti SA1 with a base-case employment CI of 2.684 would be

$$w_i = \left(\frac{ln\ T}{ln\ A_i}\right)^{\eta} = \left(\frac{ln\ 3000}{ln\ 2.684}\right)^{0.5} = 2.848$$

The linear weighting function with the same threshold and maximum weight values and that produced the same weight with be straight line between the points (*ln* 3,000, 1) and (*ln* 1.5050, 3.0) (an A_m value of 1.5050), would have a slope, *b*, of 0.2632 and intercept, *a*, of 3.1076.

$$w_i = a - b \cdot ln\ A_i = 3.1076 - 0.2632 \times\ ln\ 2.684 = 2.848$$

All project benefits accruing to trips originating in the Peppiminarti SA1 would be multiplied by an equity weight of 2.848.

Appendix C – Data sources and methodology for connectivity indexes, trip numbers and regressions

Estimation of the CIs and trip numbers and the regressions analysis was undertaken by consultants KPMG. This appendix contains extracts from KPMG (2025).

C.1 Estimation of connectivity indexes

C1.1 Data sources

Table C.1 Data sources for the connectivity indexes

Data	Data source	Relevance of the data
SA1 – 2021 – Shapefile (GDA94)	ABS	used to create SA1 centroids.
UCL – 2021 – Shapefile (GDA94)	ABS	used to create UCL centroids.
Australia-latest-free.shp.zip	Open Street Map (OSM)	This zip file contains geographic data covering Australia (buildings, traffic, roads, etc.). Using the gis_osm_roads_free_1.shp file, the road network for this study was created by filtering out items not classified as being either motorways/freeways or trunk (very important), primary (national level), secondary (regional level), tertiary (local level), and unclassified (small local) roads.
Travel Times by Car	Open Trip Planner (OTP)	Travel times data was sourced by connecting to OTP servers through R.

C1.2 Data processing

These data were processed in the following steps:

- **Create centroids for all SA1s and UCLs.** Using ABS 2021 shapefiles for SA1s and UCLs, and after data cleansing, 61,845 SA1 centroids (origins) and 1,837 UCL centroids (destinations) remained. (A total of over 113 million possible origin-destination trip combinations.)
- **Re-locate centroids to the nearest road within 40km.** SA1 centroids were relocated to the nearest road within 40km as some centroid locations were in areas inaccessible by car, such as forests, mountain ranges, river basins etc. A 40km distance was assumed in order to ensure that travel time by car could still be calculated. Where a SA1 centroid is not located within 40km of a road network, the centroid was excluded. These excluded regions are typically located in deserts near the centre of Australia and are unlikely to impact results due to low populations in these areas.
- **Remove SA1 centroids located in Major Cities.** Origin SA1 centroids in the ABS Major Cities RA were excluded. A total of 19,088 SA1 centroids remained in the origin set, yielding a new total of just over 35 million possible origin-destination pairs.
- **Remove SA1 centroids located on islands.** Origin SA1 centroids on islands not accessible by road were excluded. This was done by counting the number of neighbours within a one metre buffer of each SA1's and SA2's border. Then, those with less than or equal to one neighbour were excluded. A total of 18,861 SA1 centroids remained in the origin set, yielding more than 34 million possible origin-destination pairs.

- **Remove origin-destination pairs with a direct distance of greater than 200km.** Origin-destination pairs that are over 200km apart were removed, assuming people living in regional Australia are not willing to travel to UCLs beyond 200km for regular trips. (Around 2.1 million origin-destination pairs remained.)
- **Calculate travel times.** Calculate travel times for each origin-destination pair using Open Street Map (OSM) and Open Trip Planner (OTP) (using a calculation loop written in R). A minimum travel time of 5 minutes was set to ensure all calculated travel times were sensible, especially those between destination UCL centroids that lie within the origin SA1.
- **Create CI.** Aggregate and weight travel times for each origin SA1 to create the CI (following the functional form in Chapter 3).
- **Assume a connectivity score of zero for missing origins.** Where the centroid is more than 40km away from the nearest road and/or the closest UCL is more than 200km away, a connectivity score of zero was assumed since they were excluded due to poor connectivity.

C.2 Estimation of trips per person

C2.1 Data sources

Historical trips in regional and remote areas of Australia were estimated using data from ABS, ACARA, DE and AIHW. Table C.1 summarises the data sources. A trip is defined to include the return journey, that is, the journey from origin to destination, then destination to origin, is counted as one trip.

Employment and primary and secondary education trips were sourced from 2016 data to avoid the impacts that Covid-19 had on figures in the 2021 data. Travel restrictions and lockdowns employed in each state and territory had an impact on work commuters and primary and secondary students' attendance rates. ACARA notes its 2021 data used a different method to calculate attendance to account for remote attendance. Similarly, health data was sourced from the 2016-17 financial year to avoid the impacts of Covid-19 and the bushfires that occurred in 2021-22, which led to the introduction of a range of Medicare-subsidised services from March 2020.

Data on primary and secondary education, early childhood education, and GP trips were not available at the SA1 geography level. Data at the SA3 level had to be converted to SA1 level by assuming the same trips per person rates applied across each SA3.

Table C.2 Data sources for numbers of historical trips

Data	Data source	Relevance of the data
SA1 – 2021 – Shapefile (GDA94)	ABS	creation of SA1 centroids and identify corresponding SA3s and state/territories.
UCL – 2021 - Shapefile (GDA94)	ABS	creation of UCL centroids.
RA – 2021	ABS	identification of the RA classification for SA1s.
SA1 - 2021	ABS	provide further detail for each SA1.
SA1 Usual Residence (UR) by Age (AGEP) - 2021	ABS	population for each SA1 by age group in 2021 used in calculating the tertiary education trips.
SA3 UR by Age (AGEP) - 2021	ABS	population for each SA3 by age group in 2021 used in calculating the early childhood education trips.
SA1 UR by Age (AGEP) - 2016	ABS	population for each SA1 by age group in 2016 used in calculating the employment trips.

Data	Data source	Relevance of the data
SA3 UR by Age (AGEP) - 2016	ABS	population for each SA3 by age group in 2016 used in calculating the health trips.
RA UR by Age (AGEP) - 2016	ABS	population for each RA by state/territory and age group in 2016 used in calculating the primary and secondary education trips.
SA1 UR by Method of Travel to Work - 2016	ABS	number of people that travelled to work on Census day by UR SA1.
National Report on Schooling in Australia – Student attendance by State/Territory and Geolocation (RA) by School Year Level - 2016	ACARA	provide Year 1 to 10 school attendance rate across Australia by state/territory remoteness area.
Early Childhood June quarter 2021 – Table 8.1: Number of children, families and services by SA3 - 2021	DE	number of children aged zero to 5 enrolled in Child Care Subsidy approved childcare centre by SA3.
SA1 UR by Type of Educational Institution Attending (TYPP) - 2021	ABS	number of people that attended tertiary institutions by UR SA1.
Medicare-subsidised GP, allied health and specialist health care across local areas: 2013-14 to 2018-2019	AIHW	GP attendance rate per 100 people by SA3.
2016 SA1 to 2021 SA1	ABS	convert the trips calculated in 2016 SA1s to have a consistent geography to 2021 SA1s.
2016 SA3 to 2021 SA3	ABS	convert the trips calculated in 2016 SA3s to have a consistent geography to 2021 SA3s.

C2.2 Employment trips

The number of employment trips per person per day was calculated by dividing the number of workers by the working age population. The number of workers was sourced from the ABS 2016 Census data on the Method of Travel to Work.[36] The working age population figure was sourced from ABS 2016 Census data on age. Both data sets were extracted by SA1 place of residence (origin). These data were processed in the following steps:

- **Extract the relevant responses.** The number of people who travelled to work by any means on census day was extracted. Numbers of people who ‘Worked at home’, ‘Did not go to work’, ‘Not stated’, or ‘Not applicable’ were excluded.
- **Divide by relevant population.** The number of people who travelled to work was divided by the number of the working age population, defined as those aged 15 to 64.
- **Convert 2016 SA1s to 2021 SA1s.** Employment trips per person per day by 2016 SA1 were translated to 2021 geographies by applying the conversion ratio from the ABS.
- **Remove randomised data points.** Employment trips per person per day with numerators less than 20 people and denominator less than 50, were removed. This was to ensure the data used did not capture the

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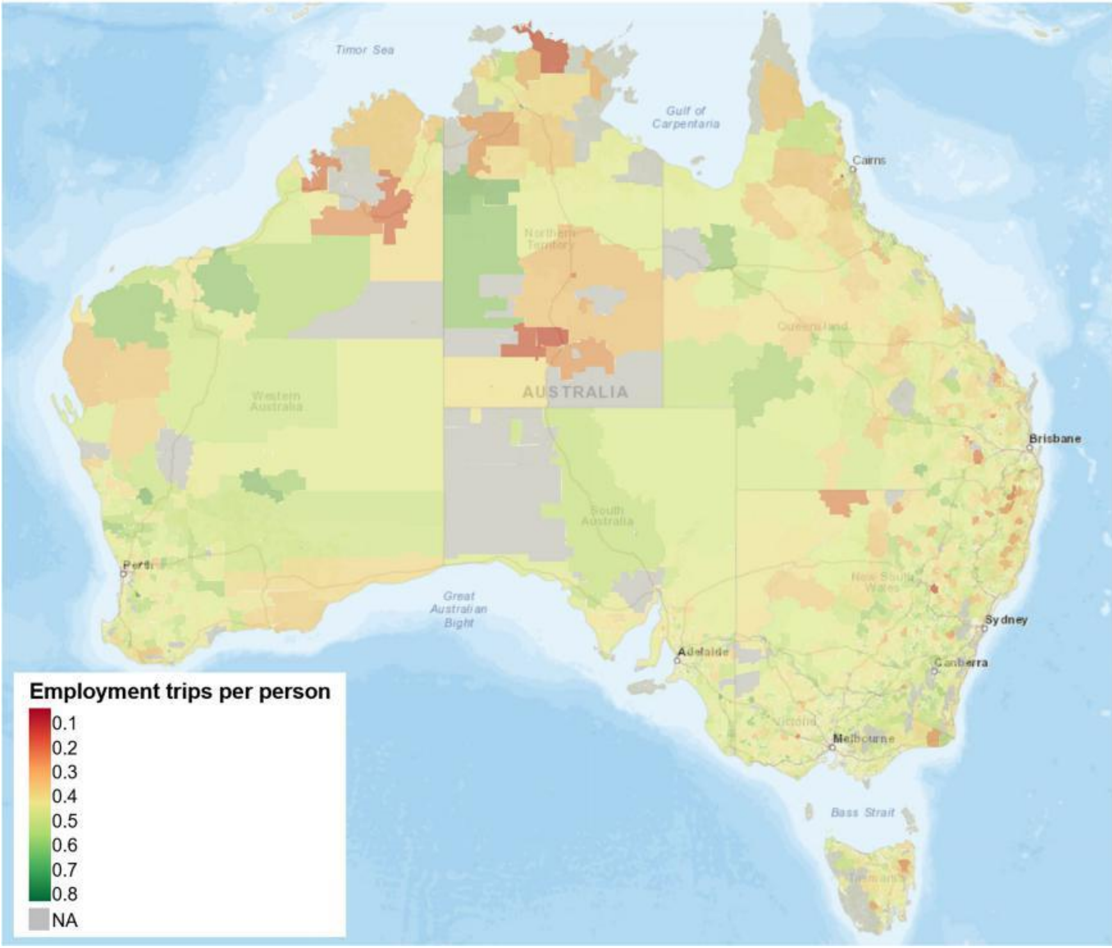
36 The question from the 2016 Census asked, ‘How did the person get to work on Tuesday 9th August 2016?’. The respondent was asked to either answer their method of travel to work, such as train, bus, ferry, car – as a driver etc., or that they worked at home or did not go to work on that day.

randomised values generated by ABS to prevent the identification of individuals in SA1s with small numbers reported. Trips per person per day greater than one were also removed.

- **Remove Major Cities and island SA1 origins.** SA1 origins categorised as Major Cities under ABS RA structure and those on islands without road access were omitted.

Figure C.1 presents the map of the employment trips per person per day.

Figure C.1 Employment trips per person per day



Source: KPMG (2025)

C.2.3 Early childhood education

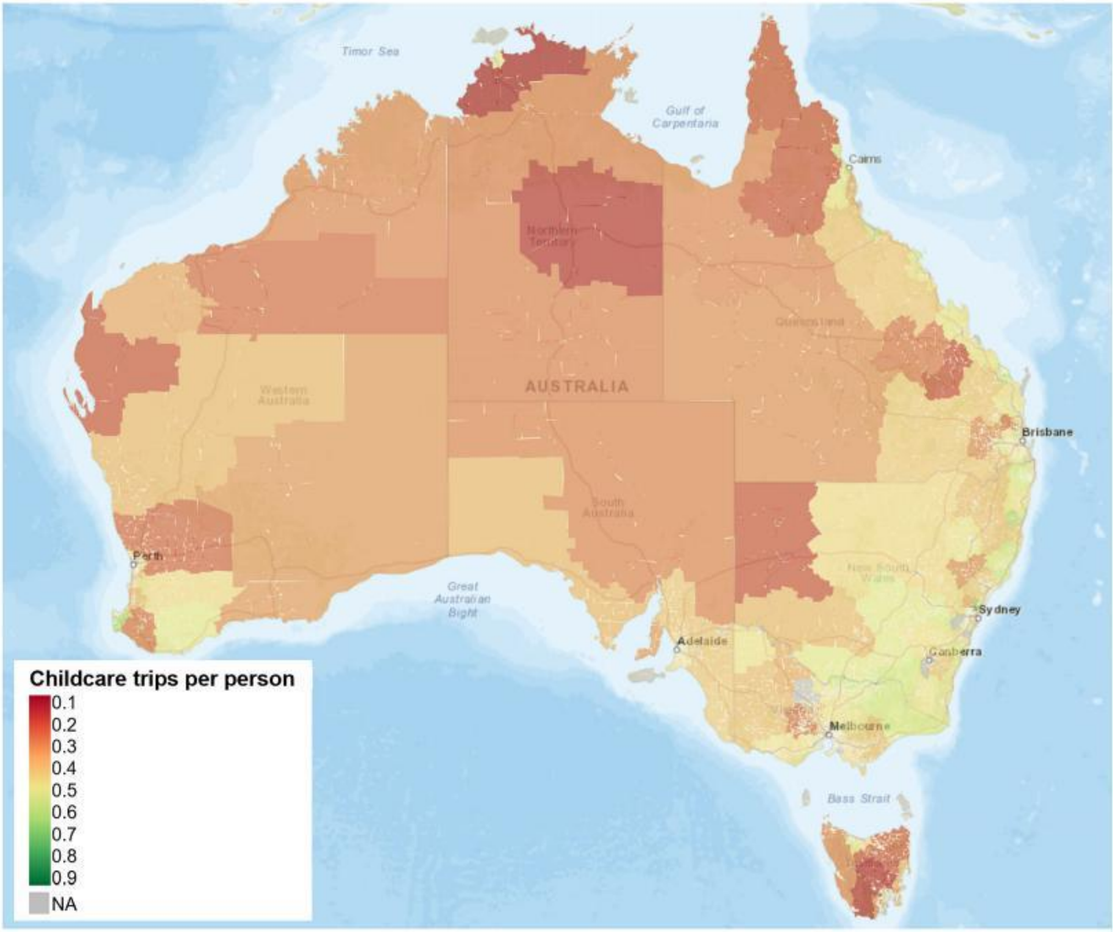
The number of childcare trips per person per day was calculated by dividing the number of children enrolled in childcare by the relevant population. The former was sourced from the DE 2021 Early Childhood data on the number of children by age group enrolled in childcare centres by SA3. The latter was sourced from ABS 2021 Census data on age. Both sets of data were extracted by SA3 place of residence (origin) for consistent geographies with the DE data. These data were processed with the following steps:

- **Extract the relevant responses.** The numbers of children aged zero to 5 who were enrolled in childcare in each SA3 was extracted from the data.
- **Divide by relevant population.** The number of children enrolled in childcare was divided by the number of children aged zero to 5 by SA3 place of residence
- **Remove randomised data points.** Childcare trips per person per day with a denominator less than 69.2 (or the 5th percentile) were removed. This is to ensure the data used did not capture the randomised values generated by ABS to prevent the identification of individuals in SA3s with small numbers reported. Trips per person per day greater than one were also removed.

- **Convert 2021 SA3 to 2021 SA1.** Childcare trips per person per day by 2021 SA3 were translated to SA1 geographies by assigning the trip values to all SA1s within each of the geographies in proportion to the relevant population in each SA1.
- **Remove Major Cities and island SA1 origins.** SA1 origins categorised as Major Cities under ABS RA structure and those on islands without road access were omitted.

Figure C.2 presents the map of the childcare trips per person per day.

Figure C.2 Childcare trips per person per day



Source: KPMG (2025)

C2.4 Primary and Secondary Education

The number of primary and secondary education trips per person per day was calculated by finding the weighted average attendance rate by school grade. The attendance rate by grade was sourced from ACARA 2016 student attendance data. The weighting by school grade was sourced from ABS 2016 Census data on age. Both sets of data were extracted by state/territory RA (origin) for consistent geographies with the data reported by ACARA. These data were processed in the following steps:

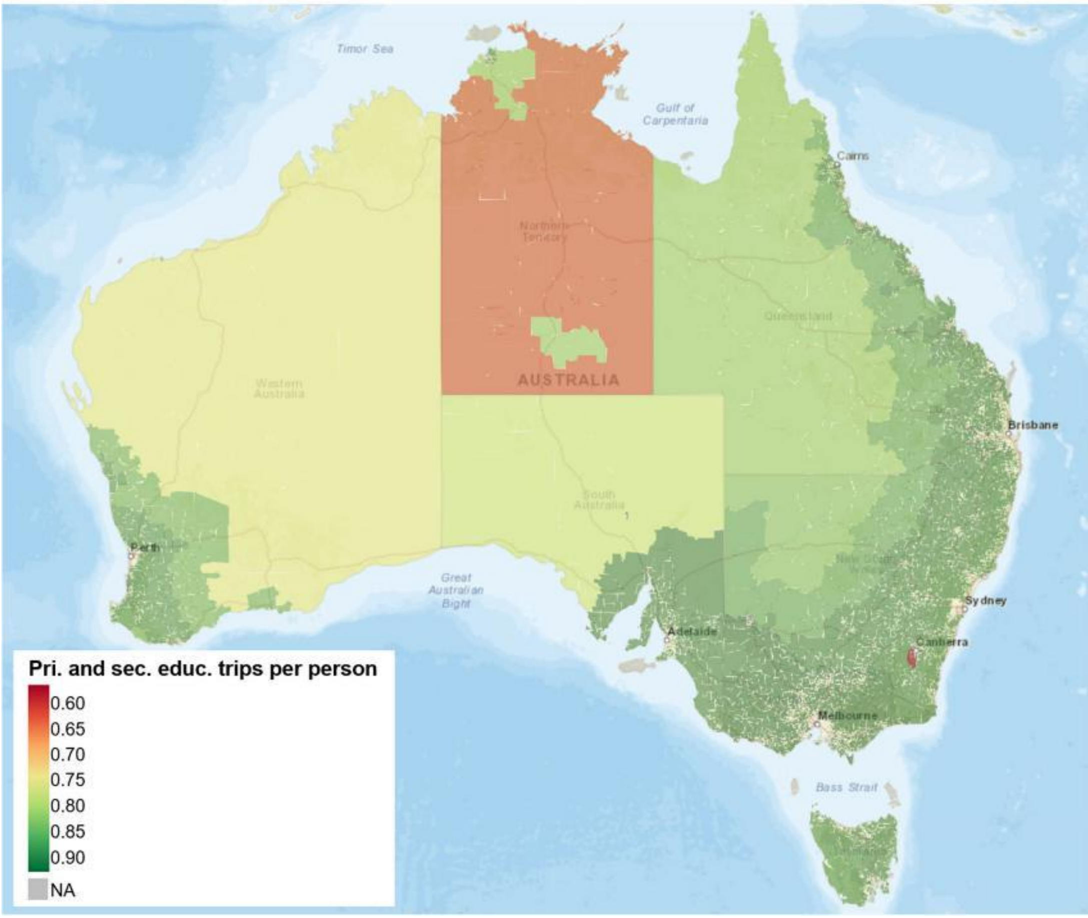
- **Extract the relevant responses.** Attendance rates across all school sectors, sex, and Indigenous status were extracted by school grade from Year 1 to Year 10.
- **Calculate the weighting by grade.** Numbers of children aged 7 to 16 was assumed to correspond to students in Year 1 to 10. A weighting was created by dividing the Year 1 aged children by the total number of children aged 7 to 16.
- **Find the weighted attendance rate.** Using the weightings by grade (*g*), the weighted attendance rate was calculated for each state/territory remoteness area (*i*). Primary and secondary education trips per person per day =

$$\sum_{g=1}^{10} Attendance\ rate_{i,g} \times \frac{School\ age_{i,g}}{\sum_{g=1}^{10} School\ age_{i,g}}$$

- **Convert 2016 state/territory RA to 2021 SA1.** Primary and secondary education trips per person per day by 2016 state/territory RA were translated to 2021 geographies by assigning the trip values to all SA1s within each of the geographies.
- **Remove Major Cities and island SA1 origins.** SA1 origins categorised as Major Cities under ABS RA structure and those on islands without road access were omitted.

Figure C.3 presents the map of the primary and secondary education trips per person per day.

Figure C.3 Primary and secondary education trips per person per day



Source: KPMG (2025)

C2.5 Tertiary Education

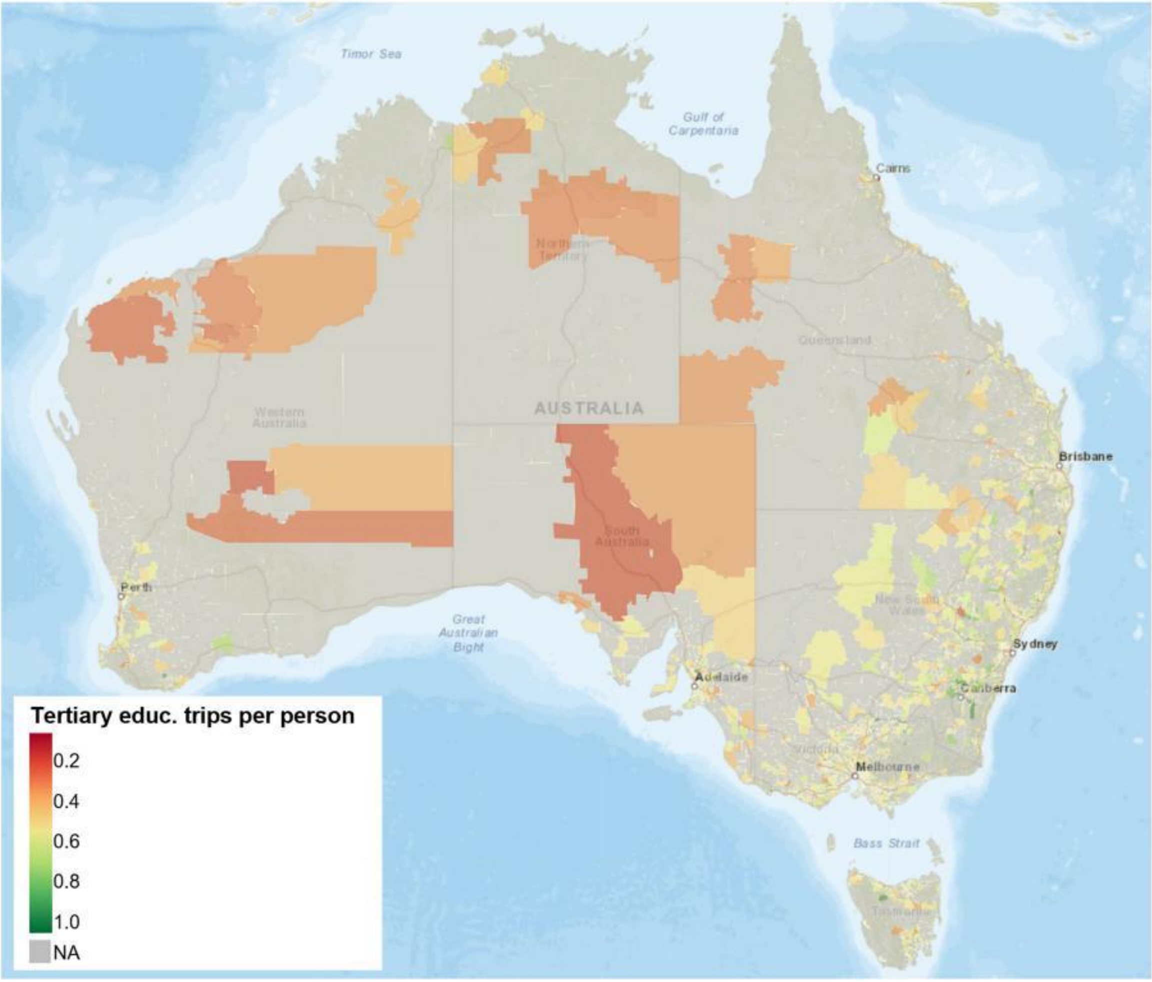
The number of tertiary education trips per person per day was calculated by dividing the number of people attending tertiary institutions by the relevant population. The former was sourced from the ABS 2021 Census data on the Type of Education institution Attending. The latter was sourced from ABS 2021 Census data on age. Both sets of data were extracted by SA1 place of residence (origin). These data were processed in the following steps:

- **Extract the relevant responses.** The number of people who attended any tertiary institution was extracted, that is, the number of people who attended either ‘Tertiary – Vocational education (including TAFE and private training providers)’, ‘Tertiary – University or other higher education’, or ‘Tertiary – not further defined’ were included.
- **Divide by relevant population.** The number of people attending a tertiary institution was divided by the number of people aged 18 to 25 by SA1 place of residence.

- **Remove randomised data points.** Tertiary education trips with numerators less than 12 people (or the 15th percentile) and denominator less than 21 (the 20th percentile) were removed. This is to ensure the data used did not capture the randomised values generated by ABS to prevent the identification of individuals in SA1s with small numbers reported. Trips per person per day greater than one were also removed.
- **Remove Major Cities and island SA1 origins.** SA1 origins categorised as Major Cities under ABS RA structure and those on islands without road access were omitted.

Figure C.4 presents the map of the tertiary education trips per person per day.

Figure C.4 Tertiary education trips per person per day



Source: KPMG (2025)

C2.6 Health

The number of health trips per person per day was calculated by converting the annual GP attendance rate per 100 people into a daily figure. The attendance rate was sourced from the AIHW 2016-17 financial year data. The data was extracted by SA3 place of residence (origin). These data were processed in the following steps:

Extract the relevant responses. The total Medicare-subsidised GP attendance rate across all persons, measured in services per 100 people, reported in 2016-17 financial year. The rate included Enhanced Primary Care, After-hours GP attendances, Practice Incentive Program services, and 'Other' GP services.

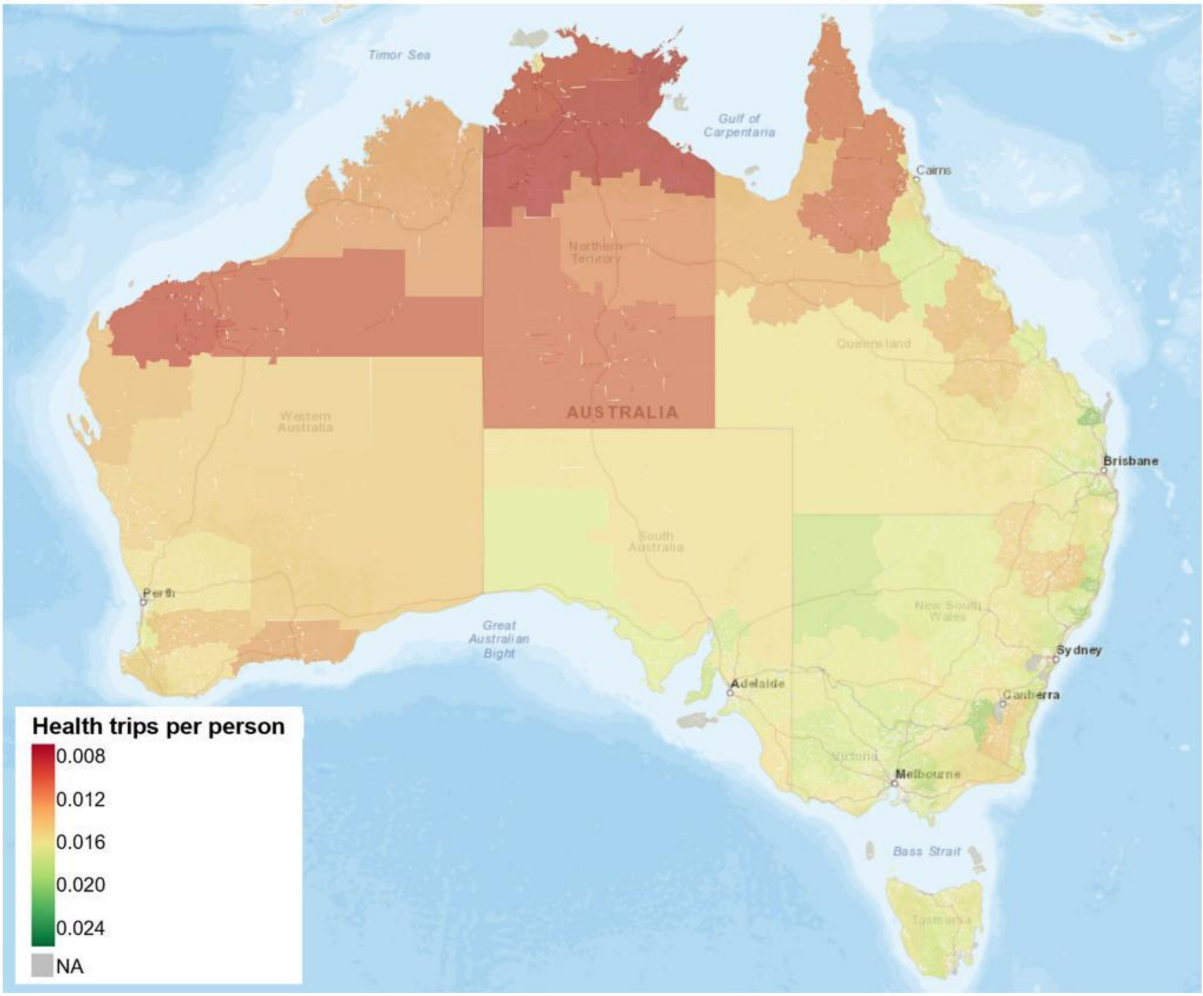
Convert to per day. The attendance rate was divided by 100 and an annualisation factor of 365 to calculate the average GP visit per person per day by SA3 place of residence.

Convert 2016 SA3 to 2021 SA1. Health trips per person per day by 2016 SA3 was translated to 2021 SA3 geographies by applying the conversion ratio from the ABS. This was converted to SA1 geographies by assigning the trip values to all SA1s within each of the geographies.

Remove major cities and island SA1 origins. SA1 origins categorised as Major Cities of Australia under ABS Remoteness Area and those on islands were omitted.

Figure C.5 presents the map of the health trips per person per day.

Figure C.5 Tertiary education trips per person per day



Source: KPMG (2025)

C.3 Regression analysis

C3.1 Form of model

Ordinary least squares regression was employed to estimate the effect of CI scores on the number of trips for each trip type, resulting in a different coefficient for each trip purpose. The regression form was the same for all 5 trip types. The independent variable was estimated trips per person per day. The dependent variables were

- connectivity score
- proportion of Indigenous population
- proportion working age 15 to 24
- proportion working age 40 to 64,
- proportion working age bachelors
- proportion working age masters or higher
- state and territory dummy variables.

The **proportion of Indigenous population** was intended to capture the employment, education and health gaps between Aboriginal and Torres Strait Islander people and the rest of the population. Population proportion was used rather than populations to avoid the effect of the arbitrarily determined SA1 boundaries and size.

The **proportion of working age population** by age group variables was intended to capture the demographic attributes of the origin SA1 without directly relating to the dependent variables. These variables have both positive and inverse relationships with the number of trips depending on the trip type and age group. For example, health trips have an inverse relationship with the proportion of working age population aged 15 to 24 relative to the 25 to 39 age group, and a positive relationship with the 40 to 64 age group. This is reflective of the increasing likelihood of having health conditions as a person ages. Population proportions were used to avoid the effect of the arbitrarily determined SA1 boundaries and size.

The proportions of **working age population by highest level of education** were intended to capture the socio-economic attributes of the origin SA1 without directly relating to the dependent variables. These variables have both positive and inverse relationships with the number of trips depending on the trip type and highest education level. For example, the proportion of working age population with the highest level of education as bachelor's and master's or higher relative to high school is expected to have a positive relationship with employment trips. Population proportions were to avoid the effect of the arbitrarily determined SA1 boundaries and size.

The proportion of the population unemployed, median age, income and other census variables were excluded to avoid endogeneity as they would be directly related to the propensity to undertake trips.

State dummies were included due to significant differences in the means of other independent variables by state and territory

A wide variety of alternative model specifications was tested including taking of logs of variables, adding the square of the CI, and interaction terms between the CI and the state and territory dummy variables. The simple linear model performed best.

C3.2 Regression results

Table C.3 presents the regression results for the 5 trip types. The regression models demonstrated an R-squared ranging from 0.279 to 0.566 across the 5 trip types. Table C.4 presents the regression coefficients. The CI and most of the control variables were statistically significant with a p-value less than 0.01 All coefficients have the expected sign.

Table C.3 Regression statistics

	Prim and sec	Childcare	Tertiary	Health	Employment
CI parameters	(–0.05, 0.6)	(–0.05, 0.6)	(–0.05, 0.6)	(–0.04, 0.6)	(–0.06, 0.8)
Observations	18,888	18,716	9,970	18,880	17,675
R^2	0.5655	0.2787	0.3290	0.4517	0.2834
Adjusted R^2	0.5652	0.2782	0.3281	0.4513	0.2829
Residual Std. error	0.0237 (df = 18,874)	0.0990 (df = 18,702)	0.1488 (df = 9,956)	0.0018 (df = 18,866)	0.0865 (df = 17,661)
F Statistic	1,889.8020*** (df = 13; 18,874)	555.7936*** (df = 13; 18,702)	1,195.4440*** (df=13; 9,956)	375.4277*** (df=13; 18,866)	537.3625*** (df = 13; 17,661)

Note: * p<0.1, ** p<0.05, *** p<0.01

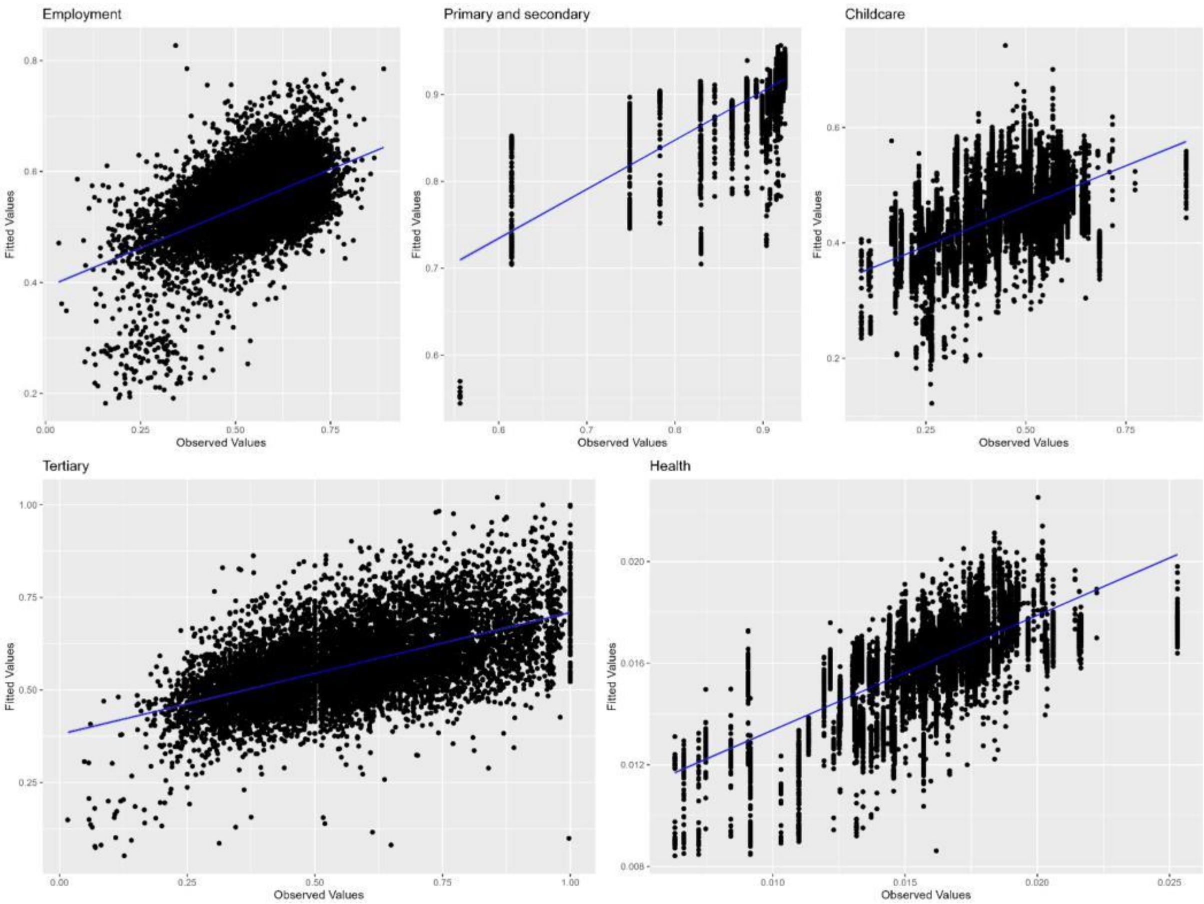
Table C.4 Regression coefficient estimates

	Prim and sec	Childcare	Tertiary	Health	Employment
CI parameters	(–0.05, 0.6)	(–0.05, 0.6)	(–0.05, 0.6)	(–0.04, 0.6)	*(–0.06, 0.8)*
CI	0.00002*** (0.0)	0.0001*** (0.0)	0.0001*** (0.0)	0.000002*** (0.0)	*0.000002*** (0.0)*
Prop. Indigenous	–0.1403*** (0.0017)	–0.1368*** (0.0071)	–0.2954*** (0.0241)	–0.0037*** (0.0001)	*–0.3469*** (0.008)*
Prop. 15 to 24	0.0322*** (0.0026)	0.0258** (0.0117)	–0.5158*** (0.0357)	–0.0009*** (0.0002)	*–0.1510*** (0.0149)*
Prop. 40 to 64	0.0125*** (0.0013)	–0.0121** (0.0055)	0.0598*** (0.0194)	0.0021*** (0.0001)	*–0.2508*** (0.0085)*
Prop. bachelor	–0.0190*** (0.0038)	0.1748*** (0.0146)	0.7482*** (0.039)	–0.0041*** (0.0003)	*0.5440*** (0.0163)*
Prop. master	0.0007 (0.0066)	0.0833*** (0.0237)	1.0159*** (0.059)	–0.0047*** (0.0005)	*0.0822*** (0.0263)*
Vic	0.0024*** (0.0005)	–0.0538*** (0.0021)	–0.0657*** (0.0044)	–0.0002*** (0.0)	*–0.0092*** (0.0019)*
Qld	–0.0006 (0.0005)	–0.0172*** (0.002)	–0.0406*** (0.0041)	–0.0001*** (0.0)	*–0.0007 (0.0018)*
SA	–0.0113*** (0.0008)	–0.0936*** (0.0032)	–0.0774*** (0.0071)	–0.0006*** (0.0001)	*0.0090*** (0.0029)*
WA	–0.0265*** (0.0007)	–0.0916*** (0.0029)	–0.0590*** (0.0065)	–0.0027*** (0.0001)	*0.0102*** (0.0026)*
Tas	–0.0005 (0.0007)	–0.0887*** (0.003)	–0.0121** (0.006)	–0.0014*** (0.0001)	*–0.0204*** (0.0027)*
NT	–0.0587*** (0.0011)	–0.0417*** (0.0045)	0.0232** (0.0094)	–0.0031*** (0.0001)	*0.0447*** (0.0043)*
ACT	–0.3626*** (0.0084)	0.0181 (0.099)	–0.1764 (0.1489)	–0.0013 (0.0012)	*0.0111 (0.0612)*
Constant	0.9033*** (0.001)	0.4188*** (0.0042)	0.4990*** (0.016)	0.0152*** (0.0001)	*0.6668*** (0.0072)*

Note: * p<0.1, ** p<0.05, *** p<0.01. Prop. = proportion

Figure C.6 presents plots of the 'observed' number of trips per person (the dependent variable) against fitted number of trips per person for each trip type. KPMG (2025) included a number of other diagnostic plots not reproduced here.

Figure C.6 Fitted vs observed numbers of trips



Source: KPMG (2025)

The state and territory dummy variables explain around half of the variation in primary and secondary education, childcare, and health trips per person. This pattern can be attributed to how the historical trips were derived for those trip types. The trips were estimated using data from the ABS Census and at geographies with less granularity than SA1s. The trips per person per day were regressed against the state dummies alone to identify whether the source data was driving the state pattern.

Table C.5 compares the R-squared values between the regressions in Tables C3 and C4 with regressions of trips per person against the state and territory dummy variables alone (all other variables omitted). The results show that substantial percentages — 12%, 35% and 29% of the variation in childcare, primary and secondary education, and health trips respectively — were explained by the state and territory of the trip origin. This pattern is due to the data sources, rather than the model specification.

Table C.5 Comparison of R-squared from state dummy regression specification and final regression

Trip type	R-squared from state dummy regression	R-squared from final regression
Employment	0.005	0.284
Education EC	0.122	0.279
Education P&S	0.347	0.566
Education Tert.	0.042	0.329
Health	0.290	0.452

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