Reducing the Societal Costs of Social Exclusion: An Opportunity for Bus

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E.1 Introduction

Development of improved transport policy directions depends substantially on better understanding how different policy options are likely to shape future economic, social and environmental outcomes. Of these three outcome areas, it is generally recognised that the social component is the least understood and developed.

Understanding how poor mobility opportunities can affect people's life chances has improved over the past two decades. Research undertaken by the current authors has shown that people with poor mobility opportunities are more likely to experience lower social inclusion and poorer wellbeing than those with better options. It has also shown that the value of an additional trip to a person at risk of mobility-related social exclusion is high (Stanley et al. 2011a, b, 2021a), leading to a finding that social inclusion is the single largest benefit produced by Melbourne's route bus services (Stanley and Hensher 2011). We note that the recent KPMG (2021) economic evaluation of Melbourne's proposed Suburban Rail Loop uses the social inclusion benefit value of a trip derived by Stanley et al. (2011a).

The social inclusion benefit in question has been seen as a measure of the monetary value of additional trip making **to those people who are at risk of social exclusion because of poor mobility opportunities**. However, social exclusion creates costs not only for the person who is excluded but also for the wider society. This is in terms of, for example, the opportunity costs of foregone employment and associated unemployment benefits, higher health costs and costs of crime, which often associate with disadvantage, as well as the compounding adverse impact of multiple disadvantages within a neighbourhood (Baumeister et al. 2005). There is thus another important class of benefit potentially available from enabling those at risk of mobility-related social exclusion to engage more fully in society: what we call **social exclusion externality benefits**. Such external benefits are occasionally recognised in general terms as resulting from better public transport services, but we are not aware of any research that has systematically measured their magnitude in a context of public transport service provision and/or improvement. Exploring the answers to such questions is the intent of this report.

In pursuing these matters, the report also takes the opportunity to revisit the way some of the direct benefits of public transport (bus) services/service improvements are measured and valued, adding a subjective wellbeing perspective. This is shown to potentially lead to higher benefit estimates than more conventional benefit valuation pathways.

Some progress in advancing the measurement of exclusion externalities is achieved in this research but the lack of hard data on dose-response relationships, as between new/improved services and wider societal outcomes, such as mental health and crime, indicates the need for a concerted research program if the real scale of this external benefit opportunity is to be more fully understood. Importantly, the paper concludes by suggesting that the inclusion benefits of additional trip making may include part of the exclusion externalities.

E.2 Project aim

This project aims to identify and measure the potential scale of social exclusion externality benefits that may be relevant to new/improved urban route bus services in cities like Melbourne, while contributing to understanding of how the quantification of such effects can be achieved. This should help to narrow the knowledge gap about the prospective benefits provided by bus services. Because this is new research in an international sense, the focus is kept to a small range of potential external benefit areas, these being potential savings attributable to increased employment levels, improved health (physical and mental) and a lower crime rate, within the context of reduced risk of mobility-related social exclusion.

In the process of identifying and measuring such potential external benefits, the paper also has a supplementary aim, which is to explore whether taking a wellbeing-based lens to transport benefit identification and measurement can provide new insights into the potential scale of public transport (bus) benefits.

E.3 Methods

For each of the exclusion externalities considered, the research approach involves four steps:

1. literature review;
2. costing the externality;
3. exploring cause-effect relationships between the externality, mobility in general and buses in particular; and
4. reporting the findings.

E.4 Costing social exclusion

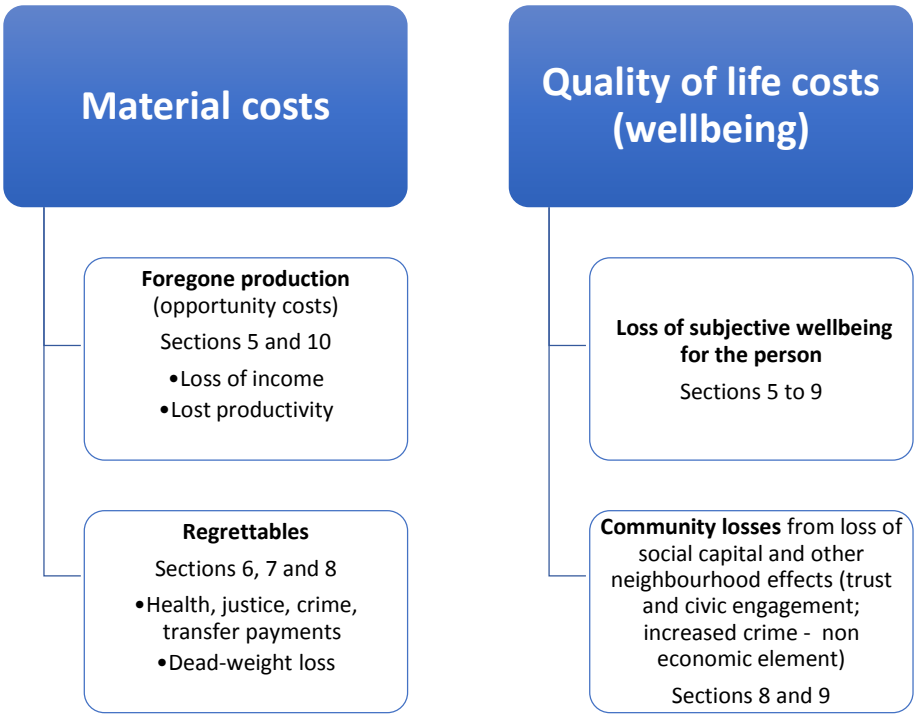
Quantifying the way that improved public transport (bus) services might reduce risks of social exclusion and, in so doing, lead to flow-on benefits from reduced exclusion externalities, requires an understanding of the costs of social exclusion, particularly those costs that might relate to mobility opportunities. These provide the starting quantum whose reduction is being explored in this paper.

Productivity Commission staff have produced a useful working paper that discusses social disadvantage in Australia and explores how to assess the costs of such disadvantage, both to the individual and to the wider society (McLachlan et al. 2013). That paper makes the important economic point that the cost of disadvantage should be assessed in terms of *avoidable costs*, which are estimated as the difference between actual and potential outcomes. Their general approach to costing disadvantage, as generally followed herein, is summarised in Figure E.1.

Figure E.1 distinguishes between *material costs* and *quality of life costs.* Material costs include (for example) costs of foregone production and health system costs, the latter included under a grouping called *regrettables* (increased public expenditure). Figure E.1 indicates where various costs are discussed in this report.

Quality of life costs are essentially losses in subjective wellbeing at individual and community level. Losses of subjective wellbeing of the person experiencing disadvantage are usually not externalities but they provide a more comprehensive indication of the scale of the costs of social exclusion or social disadvantage to the at-risk person, costs which might be reduced or avoided by improved mobility opportunities. There are good reasons to argue that such wellbeing measures are highly relevant for cost-benefit analysis, given CBA's intended emphasis on how individuals assess/value changes in their welfare. New research by the current authors and colleagues has enabled estimation of the value of changes in wellbeing (Stanley et al. 2021a). That work is relevant to measuring some of the more subjective costs associated with exclusion, the resulting measures providing a more comprehensive assessment of the costs of exclusion to the at-risk person than material costs alone. For example, the subjective wellbeing gain from moving someone from unemployment to full-time employment is greater than the income gain to the person involved, as shown in Section 5.

Figure E.1: Framework for costing disadvantage
(drawing on McLachlan et al. 2013)



E.5 Improved employment outcomes

Research reported in Section 5 of the report concludes that a value of $90,000 (2019 prices) is a reasonable estimate for the annual value of the gain in subjective wellbeing realised by a person moving from being unemployed and looking for full-time (FT) work to being employed FT. That valuation draws on original research undertaken by the authors and colleagues and reported herein. This amount is greater than the net increase in earnings realised by the person in question, which looks likely to be considerably less than $75,000, which was average weekly earnings (persons) at the time.

The subjective wellbeing figure is a defensible estimate of the scale of benefits to the person who moves from unemployment and looking for FT work to being employed FT. Valuing the benefit of such a change in employment status solely by looking at the earnings gain to the person who moves to FT employment risks substantially underestimating the relevant benefit for evaluation purposes. Savings in unemployment payments are a separate and additional benefit, to Government revenues, perhaps valued at around $17,000 per person moving from unemployment to FT employment.

PT/bus service improvements that enable someone to shift from unemployment to employment are thus potentially worth over $100,000 a year per added job, valued as increased subjective wellbeing plus savings in government welfare payments. This is a potential additional benefit from the PT/bus service improvement. Depending on how the service improvements are funded, there may be offsets that need to be recognised, as noted in Section 11.

Transport improvements may also generate agglomeration (productivity) benefits, following increases in effective employment density that those improvements might stimulate. Section 10 of the report discusses agglomeration effects, which are external effects that may associate with initiatives to reduce exclusion.

E.6 Physical health

The Australian Institute of Health and Welfare (2019a) suggests that Australian health costs totalled $195.7 billion in 2018-19. The main interest in the current paper is not with health per se but with to what extent health might be improved by enhanced mobility opportunities, with resulting benefits in the form of lower health costs and/or increased subjective wellbeing. This requires, inter alia, drilling down into health data to identify potentially avoidable health conditions.

It is in the area of chronic conditions (lifestyle related) that mobility improvements might be most relevant to improved health outcomes and reduced health system costs. In particular, increased active travel, including the walk part of a bus trip, is one way of contributing to health benefits, being recognised as a means of achieving the recommended minimum of 30 minutes a day of moderate exercise.

Figure E.2 explores the walk distances of Melbourne PT users revealed by VISTA data for the 2012-18 period. Walk times for PT users who use bus at any given distance from central Melbourne are less than walk times for train/tram only users, which is not unexpected: it has long been known that people will walk further to access a faster mode and rail, with its own right-of-way, is usually faster than bus, which typically must battle in mixed traffic streams. Nonetheless, PT users who used bus as a stand-alone mode still typically get around 30 minutes daily walking time, or more than this if they live closer to the centre of the city. If they use bus and train or tram, then walk times mirror those for train/tram only users, up to 20-25kms residential distance from the CBD. Bus use is thus one way for an adult to incidentally get the minimum recommended 30 minutes of daily moderate exercise.

The incidence of self-reported obesity and heart disease tends to be greatest in the outer suburbs, which are at the longest distances from the CBD, and it is just these areas where bus service levels are lowest, measured in terms of services per stop per day, as shown in Figure E.3. Few bus/tram services per stop in Melbourne's outer urban growth suburbs meet a benchmark of 55 services a day, which would represent 20-minute headways for 18 hours a day, consistent with the Plan Melbourne idea of Melbourne as a series of 20-minute neighbourhoods (DELWP 2017).

Section 6 thus identifies solid support for recognising the walking associated with an adult bus trip as having health benefits. It argues that this benefit can be valued at around $3.25 per bus trip. This value is based on values derived in TIAC (2016) Active Travel Guidelines, based on morbidity and mortality costs and health system cost savings, but with more conservative assumptions about walk distances/speeds than implied in the TIAC work. This value suggests that the walking (physical health) benefits from Melbourne's route bus services are currently of the order of $200 million annually, in 2019 prices.

Walking associated with PT use also has benefits in terms of improved subjective wellbeing but the evidence base about dose-response relationships is not solid enough at this time to put a reliable monetary value on those subjective wellbeing benefits. Walking is also beneficial for the physical health and wellbeing of children and youth but again there is not sufficient evidence at this time to put a monetary value on those benefits to these cohorts.

Figure E.2: Average daily minutes of walking: Greater Melbourne residents, by whether public transport was used on survey day and home distance from CBD
(Source: Chris Loader)

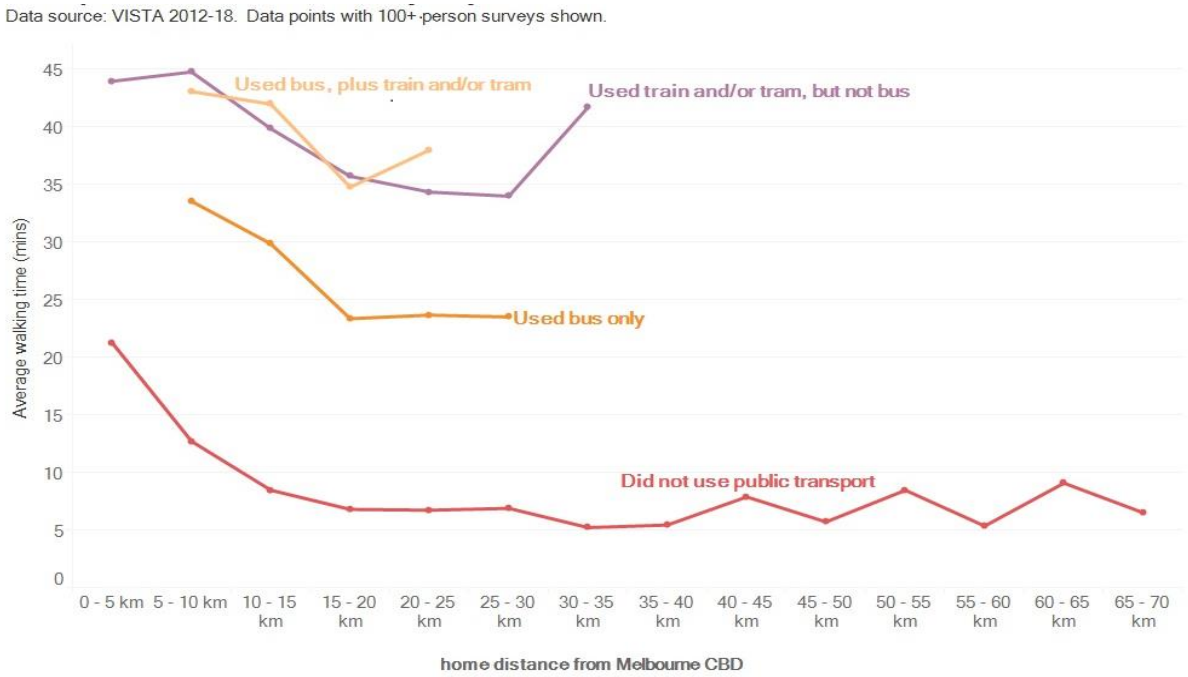
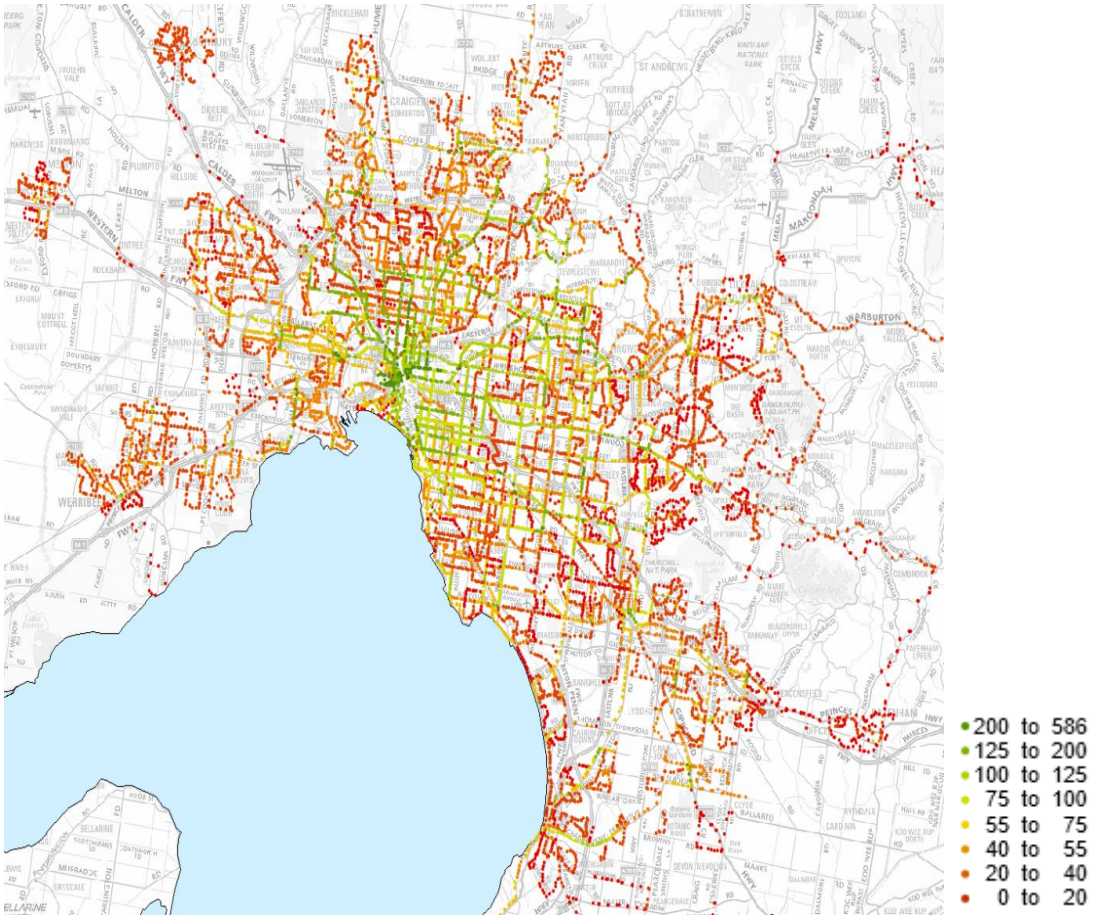


Figure E.3: Melbourne's route bus and tram services: services per stop per day on a typical weekday (each direction; 2019) (Source: PTV GTFS feed)



E.7 Mental health

Poor mental health is a large and growing problem in Australia. There has been a major focus on this area in recent years, with the Productivity Commission (2020) suggesting that it costs Australia over $200 billion annually. The Commission suggests that 10 million Australians are at risk of mental illness.

It is likely that the ability to be mobile would assist in reducing the high personal and societal cost of poor mental health, through direct access to support, services and treatment. The ability to be mobile would also be likely to aid the restoration of health through enabling a reduction in factors that lead to, or exacerbate, a mental health condition, through facilitating the important role of social interaction or social connectedness towards the achievement of health and wellbeing. This link between transport and mental health and wellbeing is a greatly under-researched area that is likely to show high value if the connections are measured.

Our research sought evidence about possible connections between improved mobility opportunities and better mental health. General expectations about such outcomes were found but no quantitative evidence to support valuation of such influences was identified. The most likely pathway for such quantification we expect will be via improved mobility opportunities improving social capital (social connectedness), since there is then an evidence base supporting a link from improved social capital/connectedness to some aspects of improved mental health. There is a scant evidence base here, however, not helped by different researchers adopting different ways of defining social capital or connectedness.

E.8 Crime

Crime, like mental health, imposes huge economic costs. Smith et al. (2014) measured costs of crime at around $50 billion in 2011 prices, recognising that many costs were not part of these measurements. The causes of crime are far from established in the literature, but two broad causes are accepted, being the functioning of the family and poverty/disadvantage. Some researchers suggest that community connections between individuals and how organisations impact the capabilities of individuals, along with mutually supportive practices between schools, parents and other organisations, will impact crime outcomes.

We found little research evidence around connections between crime and infrastructure/land use transport planning. Some possible areas of application are worth considering. For example, poor land use transport planning associated with rapid population growth on the urban fringe might be expected to lead to concentrations of problematic and antisocial behaviours, which can include fire lighting, as illustrated in a case study included in Section 8. We found a small amount of work on the physical structural qualities of a neighbourhood and land-use planning, and Section 9 of the report includes new research we have undertaken with colleagues on mobility, neighbourhood disadvantage and social exclusion. However, as with mental health, we are yet to find work on the role of transport or mobility in crime prevention. As with mental health, we expect that links between mobility and social capital or social connectedness is likely to be a fruitful pathway for examination, in this case leading to differing crime outcomes.

E.9 Community/neighbourhood level effects on risk of social exclusion and implications for the value of mobility

Section 9 considers whether there might be external benefits from mobility improvements that accrue at community or neighbourhood level, in addition to those that arise at the level of an individual, the latter having been the focus of the report thus far. The substantial contribution of Professor David Hensher to this section is gratefully acknowledged.

Analysis undertaken for this report demonstrates that neighbourhood disadvantage in Melbourne, at postcode level, is a significant *additional* explanatory variable for risk of social exclusion, particularly for the most disadvantaged areas, alongside person-level influences such as trip making, social capital, sense of community and household income. However, neighbourhood disadvantage only provides a small contribution towards explaining risk of social exclusion, beyond that from the variables included in Stanley et al. (2011a, b, 2021a) associated with individual-specific influences. Also, because of the composite nature of the neighbourhood disadvantage variable used herein, which is based on the ABS SEIFA Index of Relative Socio-Economic Disadvantage, the finding that it makes a small but significant contribution to exclusion risk does not easily lead to identification of suitable specific neighbourhood scale policy interventions or valuation thereof.

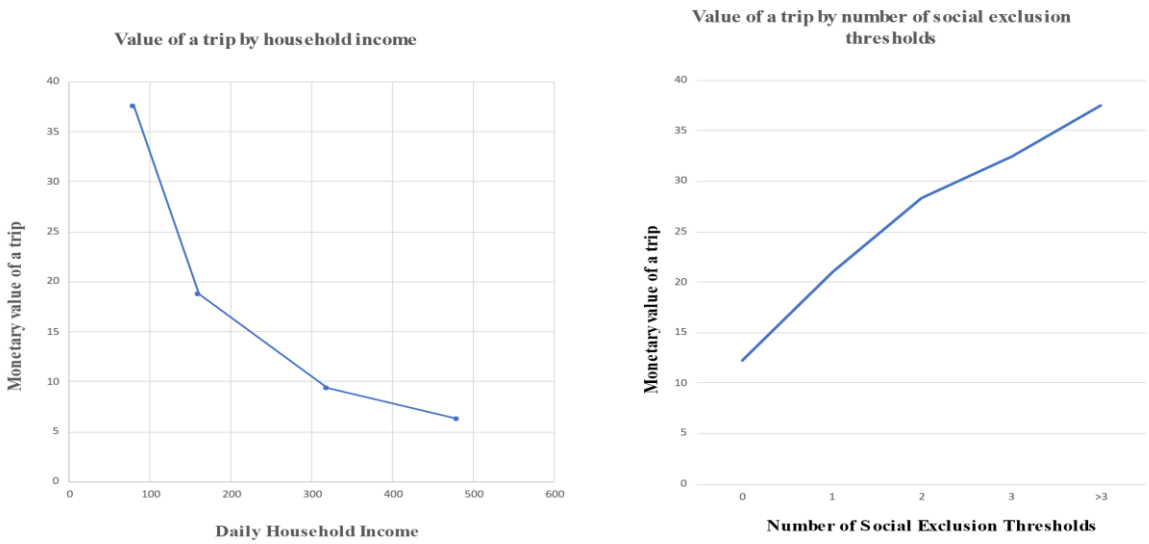
The inclusion of neighbourhood disadvantage, as measured herein, does not reduce the potential value of transport initiatives to reduce social exclusion. Additional trips are still valued highly as a contributor to reducing risk of social exclusion, at a mean sample value of around $15-20 per trip (estimated at $20.40 in Section 9 of this report), all values expressed in 2008 prices for metropolitan Melbourne (Stanley et al. 2011a, b, 2021a), or $22-30 per trip in 2019 values.

The analysis finds that, in terms of reducing risk of mobility-related social exclusion, the value of additional trips increases as the number of exclusion risk factors increase. This is a new finding. Conversely, the value of an additional trip is shown to fall as household income increases, as found in Stanley et al. (2011b, 2021a). Figure E.4 shows these relative trip values, as exclusion risk levels change and as household income changes.

A policy focus on transport initiatives to reduce exclusion risk should preferably use values for additional trips that are based on different exclusion risk levels in appraisal work, rather than trip values based on relative household income levels. A challenge here, however, is that identifying the number of exclusion thresholds confronting individuals (or households), as measured herein, requires bespoke surveying. This is costly and is seldom possible, whereas data on household income is usually widely available, certainly on a spatial basis. For application purposes, given the difficulty in bespoke surveying, the authors conclude that using household-income based values for additional trips for transport appraisal work is a practical approach. This has the advantage of aligning with other income-based equity-weighting work sometimes used in cost-benefit analysis. Development of measures of individual risk of social exclusion that do not rely on bespoke surveys would assist application of trip values that reflect such exclusion risk. The authors are continuing to explore this issue.

Most importantly, in terms of the subject matter of the current report, the authors suggest that the value of additional trips as estimated herein, in a context of reducing risk of social exclusion, is likely to be picking up some of the savings in the external costs of social exclusion that will follow such increased trip-making, such as costs associated with crime, mental and physical health, economic output and productivity. This helps to explain why the trip values in question appear to be considerably higher than is implied by the economists' rule-of-a-half as conventionally applied to evaluate the benefits of additional trips. Further research on this grossly under-researched topic is encouraged.

Figure E.4: Variation in the value of additional trips, against household income and exclusion risk level



E.10 Case studies on major transport expenditure initiatives

This section of the report uses some of the findings from preceding sections to explore whether the benefits from major urban transport spending increases are likely to differ greatly, depending on whether that spending prioritises light rail, major road network improvement or provision of additional bus services and on the extent to which the focus of the initiative in question is on reducing risk of mobility-related social exclusion. A Sydney case study provides the focus of the research, undertaken using modelling by Professor David Hensher, Dr Edward Wei and Dr Wen Liu at the Institute of Transport and Logistics Studies, The University of Sydney Business School.

A land use and transport planning model system (MetroScan) is used for the assessment of four major transport initiatives in Sydney: Stage 1 of the Parramatta Light Rail; a major motorway (M4) upgrade; and, two

alternative doublings of bus service frequencies, one that is widely spread across Greater Sydney and the other which is concentrated in the west, one of the more disadvantaged parts of Sydney. The intent was to enable a comparative assessment of the economic merits of these substantially different transport alternatives.

All four initiatives are shown to produce positive net benefits, user benefits being the main contributor to this result for the motorway and both bus upgrade projects, with social inclusion benefits the main justification for the Parramatta Light Rail Stage 1 and also forming a key benefit component of the bus upgrade project that is focussed on Sydney's west (areas at relatively greater risk of mobility-related exclusion). The integrated transport (passenger and freight) and land use modelling approach, with feedback between travel and location decisions, also shows the importance of benefits to freight movement for each of the four initiatives.

Agglomeration benefits (an externality) are one focus of many transport appraisals. The nature of the transport and land use interactions reflected through the MetroScan model have been important in illustrating the potential for considerably different agglomeration tendencies, some positive but others negative. The potentially negative agglomeration impact of a major road upgrading project is a cautionary finding in an Australian urban setting, as is potential negative agglomeration effects from bus frequency increases in outer suburbs. We return to this issue in the Conclusions section below.

The assessments reported herein show some small benefits from reduced GHG emissions from the three public transport projects but increases for the road upgrade. Increased air pollution is predicted for all four projects (albeit minimal for Parramatta Light Rail), largely because of the impact of additional freight movement. However, the most important conclusion from the environmental assessments is the urgency of policy change to drive much lower Australian transport GHG and air pollutant emissions. The scale of emissions reductions that might flow from major transport projects, such as those evaluated herein, is miniscule relative to the reductions that will be needed in coming years. Regulatory solutions will need to be front and centre (e.g., updating our EURO emission standards to best practice levels). State governments are showing a lead by the phased electrification of their bus fleets.

The solid economic performance expected from both variants of wide scale doubling of bus frequencies is notable (benefit cost ratios of ~1.9 in both cases at 7% real discount rate). Rarely is such an option included as part of a city's transport strategy, often because governments and their treasuries dislike committing to ongoing service delivery costs: once-off outlays on big capital works seem to have greater political appeal. This assessment has shown that widespread upgrading of bus service frequencies can deliver good economic returns, suggesting they should be one option considered within integrated urban transport strategies for Australian cities.

A key finding from these Sydney case study examples is the importance of social inclusion benefits for targeted PT projects. Without those benefits the Parramatta Light Rail would have looked like a white elephant. With their inclusion, it measures up well. These benefits were not adjusted for household income but, if such adjustment had been made, the PLR and outer western bus frequency upgrades would have had even better evaluation outcomes, suggesting that taking account of who gains and loses is important in project appraisal.

Inclusion benefits from bus frequency increases on services in areas of disadvantage are shown to significantly support project viability. Surprisingly, social inclusion benefits are rarely counted in transport cost-benefit analyses, even though providing travel opportunities for transport disadvantaged people has long been a primary reason for provision of PT services. The recently released economic evaluation of Melbourne's proposed Suburban Rail Loop is a notable exception (KPMG 2021), drawing on trip values from our earlier research (Stanley et al. 2011a). The estimation of social inclusion benefits in the current study shows that these benefits are potentially very significant and should form part of the assessment of all major transport initiatives, and particularly for public transport and active travel initiatives.

E.11 Conclusions

Improved bus services, particularly in outer/middle parts of Australian cities and in regional areas, are a way to reduce risks that people will be socially excluded because of poor mobility opportunities. Improved bus services can both increase the likelihood of social inclusion of individuals and reduce the costs that society incurs when people are socially excluded. These wider societal costs include costs associated with poor physical and/or mental health, increased crime and reduced economic productivity.

This paper shows that when the relevant gains or losses are measured in terms of the monetary value of the gain or loss in individual subjective wellbeing, they are typically larger than when measured as changes in directly applicable costs, such as health system costs or income changes. Valuation in terms of changes in subjective wellbeing is consistent with one of the fundamental value judgements that underpin cost-benefit analysis – that individual preferences should be normative for social choice.

A change in employment status, from unemployed to full-time employed, will obviously benefit the job winner. If employment density increases, it may also generate agglomeration economies (benefits), which are a positive external (societal) benefit. Section 10 of this report has

shown that widespread doubling of bus service levels can create such agglomeration economies (benefits) but may also lead to agglomeration costs, if those service improvements are concentrated in low density outer areas. In the latter case, improvements may encourage faster outer urban growth, which can lead to lower effective economic density and agglomeration costs, not benefits. This does not mean that bus services should not be improved in outer urban areas, since social inclusion benefits will typically be highest in such settings. It means that risks of agglomeration losses should be recognised when such bus service improvements are undertaken, with improved bus services being integrated with further urban development initiatives that will directly increase outer urban densities, in line (for example) with the Victorian Government's planning philosophy of 20-minute neighbourhoods. This is about integrated land use transport planning for complete communities, not isolated thinking about isolated initiatives.

The most readily quantifiable external exclusion benefit identified in this report is associated with the adult physical health benefit of walking, linked to bus use. The research undertaken for this project also sought evidence about possible connections between improved mobility opportunities and better mental health and a lower crime rate. A few sources noted some general expectations about such outcomes but no quantitative evidence to support valuation of such influences was identified. The most likely pathway for such quantification we expect will be via improved mobility opportunities improving social capital (social connectedness), since there is an evidence base supporting a link from improved social capital/connectedness to some aspects of improved mental health and reduced crime. However, research in this area (linking improved mobility to improved mental health and reduced crime) is scarcely at the starting gate today. Our own research on connections between mobility and social capital may be worth taking further in this regard.

The report includes new analysis on the contribution of (spatial) neighbourhood disadvantage to an individual's risk of social exclusion, finding that this is a significant but small contributing factor, alongside those individual socio-economic characteristics identified in our prior research. The value of trip making, as it contributes to reducing exclusion risk, was then re-estimated herein (Section 9), taking account of the neighbourhood disadvantage effect, finding that an additional (bus) trip is worth around $22.75 in 2019 prices to someone at risk of mobility-related social exclusion. The value is higher for those at greater risk of mobility-related exclusion and lower for those at lowest risk. This value of additional trips is about 3 times the value that would be attributed to additional trips by the traditional economists' rule-of-a-half in user benefit assessment.

The $22.75 trip value is, prima facie, not an externality: it is mainly a measure of the value of an additional trip to a person at risk of mobility-related social exclusion. The report suggests that this seemingly high trip value, by comparison with values from applying the rule-of-a-half, is likely to be attributable to two factors:

- taking an additional trip, for someone at risk of mobility-related social exclusion, is a non-marginal activity, since it will mean taking (for example) four trips a day instead of three, which is a substantial relative increase (one-third). For such a change, the value (consumer's surplus) that is expected from the activity associated with that additional trip should be included as part of the trip value that has been enabled by the transport initiative under consideration – this activity value would not have been created otherwise. The rule-of-a-half, by comparison, refers to marginal (small) changes across large numbers of trips/trip makers (e.g., a saving of one minute on a car trip). The $22.75 trip value is, somewhat reassuringly, close to what the rule-of-a-half might indicate is the value for a new trip by the most expensive but most widely available alternative mode for most urban trips = a taxi, a theoretical choice only for many who are socially excluded; and
- we believe that the $22.75 value is picking up part of the external costs of social exclusion, which are a consequence of an aggregation of the personal costs of exclusion across large numbers of people. When large numbers are excluded, societal costs also rise for all. When numbers who are excluded fall, so will the wider societal costs. The way that the model that estimates risk of social exclusion is specified may mean that it is picking up some (unknown) part of the wider societal costs of exclusion. We think this is highly likely and that using the $22.75 value of a trip is going some way to monetising exclusion externalities. Adding separate estimates of particular societal exclusion costs may then pose questions of possible double counting of benefits.

The report has taken the opportunity to compare the benefits and costs of doubling bus service frequencies across large parts of the Sydney bus network with building the Parramatta Light Rail and widening the M4. The assessment shows a strong benefit-cost result for both the doubled bus frequencies (benefit-cost ratios of ~1.9). When that frequency increase is very widely dispersed, bus user benefits are strong. When it is more focussed on areas of higher exclusion risk, inclusion benefits are strong, supporting user benefits. These results show the importance of strategic transport policy and planning looking not only at large infrastructure projects but also at opportunities provided by major increases in bus service levels, as distinct from small numbers of isolated service improvements.

An issue that requires further research is the extent to which the benefits of employment increases predicted to be associated with major transport initiatives, such as the Sydney case studies included in this report, should be monetised and counted as additional benefits in a cost-benefit analysis of those initiatives. The Sydney case studies have shown this could amount to a very sizeable benefit. However, potential employment losses associated with funding of the relevant transport initiatives would then need to be recognised and counted in benefit-cost assessment. Exploring this issue is beyond the scope of the current paper but should be considered in the Melbourne project being undertaken by NIEIR for BusVic.

In summary, the report has advanced the pursuit of quantification of the external costs of social exclusion, while showing the importance of social exclusion as a transport policy challenge and the role that major increases in bus services can play in helping to mitigate mobility-related social exclusion. Further work on the mental and physical health benefits of improved mobility might be fruitful areas for further research, to build on the foundation provided in this report.

1. Context

Development of improved transport policy directions depends substantially on better understanding how different policy options are likely to shape future economic, social and environmental outcomes. Of these three outcome areas, it is generally recognised that the social component is the least understood and developed.

Good social outcomes are often considered to be about reducing the level of disadvantage experienced by some people. *Disadvantage* is a broader term than poverty and is usually seen as a context where multiple conditions co-exist which reduce life chances, such as low income, poor quality housing, being unable to afford to run a car and experiencing poor health. It is relatively more common for some groups to experience such issues, including those who are unemployed, some people with a disability, new migrants and Indigenous Australians. Disadvantage can also refer to the idea of *community disadvantage*, where a place or neighbourhood is largely comprised of people experiencing disadvantage.

In Victoria, about 25% of the population experience some disadvantage which reduces their capacity to be engaged in society, a further 13% experience considerable disadvantage and about 6% are highly disadvantaged (Stanley et al. 2017). This latter group includes those who are likely to experience multiple conditions, such as being long-term unemployed, homeless and/or supporting people in the household with a severe disability.

In Victoria, the rapid growth of the outer suburbs pre-COVID has exposed poor land use transport planning and lagged infrastructure and service provision, compounding problems of disadvantage (Brain et al. 2018). Residents in the six fastest growing outer metropolitan Local Government Areas of Greater Melbourne, for example, fared poorly relative to the state as a whole over the 1992-2017 period, in terms of their ability to generate income, and on many social indicators. The lack of public transport in outer suburbs, which means high car dependency, low density development patterns and a lack of local jobs are contributing factors, leading to high proportions of outer-urban commuters with two-hour commutes, or longer, compounding traffic congestion. Disadvantage in these suburbs is evident when compared with the rest of Victoria, in terms of (for example) lower personal economic capital, education levels, trust in others and higher levels of self-reported heart disease and obesity (Brain et al. 2018). Disadvantage is also relatively more common in regional and rural areas that experience accessibility problems.

Social exclusion (and its opposite, social inclusion) is the term used in this paper to discuss social outcomes of transport interventions, rather than disadvantage (the two are sometimes used as alternatives). Social exclusion is informed by a strong theoretical base developed by authors such as Sen (1993) and Nussbaum (1999), where the focus is on developing people's *capabilities* to participate. Nussbaum (1999) argues that achievement of capabilities is a combination of opportunities available for individuals to choose and to act, as well as the political, social and economic environment being available from which to choose. Mobility is a pre-condition for realisation of many capabilities.

Transport planning has largely overlooked planning for people who are experiencing social exclusion, focusing more commonly on initiatives that might generate time savings for the commuting trip, reduce congestion (often only temporarily) and/or safety issues (Stanley 2011). In part, this is because those experiencing social exclusion are often 'hidden' to transport planners, as they may not own cars or regularly commute to work. There also tend to be other agendas shaping transport investment, such as politicians wishing to leave their legacy, or a project may be used as a job creation opportunity (Terrill et al. 2021a). This lack of attention to disadvantage/exclusion is also due in part to transport project evaluation being usually informed by cost/benefit analysis, which is reliant on more readily measurable or tangible outcomes, such as time savings. As pointed out by Manaugh et al. (2015), it is not helped that social indicators remain frustratingly abstract, to the extent that they exist at all. This has led to the major purpose of transport commonly being overlooked. Transport is a derived demand that enables people to undertake activities that can increase their wellbeing, but wellbeing outcomes are not measured. Furthermore, those without transport, or with poor travel opportunities, may not even have this opportunity!

Understanding of how poor mobility opportunities can affect people's life chances has improved over the past two decades, particularly due to work such as that by UK Social Exclusion Unit (SEU 2003), Mollenkopf et al. (2005), Lucas (2012) and others but the field remains only in an early stage of development. Importantly, the capabilities approach is somewhat different to the accessibility planning approach that has flowed from the early work done by the SEU. That accessibility planning approach typically makes assumptions about the purposes for which people want to travel (e.g., to work, school, shop, etc.), rather than addressing the complexity of needs and the process of building wellbeing (e.g., by supporting travel that builds social capital, such as connecting people, recreational travel or visiting friends and other networks, such as associated with schools, jobs, sports, etc.). This trend has continued into much of the research on

transport and disadvantage or poverty (e.g., Litman 2014, Pereira et al. 2016).

Australian research has explored associations between transport disadvantage, social exclusion and wellbeing (Currie 2011). Research undertaken by the current authors (e.g., Stanley 2019, Stanley 2018, Stanley et al. 2011a, b, 2012, 2021a) has shown that people with poor mobility opportunities are more likely to experience low social inclusion and poor wellbeing than those with better options. It has also shown that the value of an additional trip to a person at risk of mobility-related social exclusion is high, Stanley and Hensher (2011) concluding that social inclusion is the single largest benefit produced by Melbourne's route bus services.

The social inclusion benefit in question is a measure of the monetary value of additional trip making **to those people who are at risk of social exclusion because of poor mobility opportunities**. This benefit is the basis of bus services sometimes being described as having the characteristics of a *merit good*. Stopher and Stanley (2014, p 24) describe a merit good as:

> *"... one which society, through its political processes, has decided should be provided on the basis of considerations of need rather than ability and willingness to pay. The good is provided in the private marketplace, but there is a social decision to ensure some base level is available, irrespective of individual preferences or circumstances."*

There are two aspects of the merit good argument. First, recognition that if providing this good is left to the private marketplace, some people will consume or use less of it than is in their best long-term interest (perhaps because they cannot afford more). Second, this lower level of consumption/use is recognised as leading to lower levels of both personal and wider societal well-being. Education is perhaps the best-known example of a merit good, where higher levels of education than might result if this was left solely to the private marketplace are seen as being good for both the individual and for the wider society.

For societies that place a value on social inclusion, recognition that poor mobility opportunities may increase the risk that some people will be socially excluded often leads to subsidisation of public transport services, as a form of social safety net. The value of the measured social inclusion benefits **to Melbourne route bus users** has been demonstrated as being much greater than the total government budget cost of providing those services (Stanley and Hensher 2011). However, exploration of the wider societal costs that might be associated with social exclusion linked to poor mobility opportunities has received no serious research attention.

Building on the wider societal benefit aspect of the merit good argument, it is important to understand that disadvantage or exclusion is not just a problem for those experiencing this condition. Wilkinson and Pickett (2010) show that inequality tends to produce poorer outcomes for all people in the society across a range of indicators, such as levels of trust, life expectancy, obesity, mathematics and literacy scores, and homicide rates. Wilkinson says:

> *"The big idea is that what matters in determining mortality and health in a society is less the overall wealth of that society and more how evenly that wealth is distributed. The more equally wealth is distributed the better the health of that society."*

(Wilkinson 2021)

Those who are socially excluded are more likely to experience negative emotions, such as fear, hostility, anxiety and sadness (Stanley et al. 2017). Inequality erodes social capital, the degree to which individual citizens are involved in their society, the strength of the social networks within it, and the degree of trust and empathy between citizens (Wilkinson 2021). More equal societies even appear to be more innovative than others (measured by the number of new patents registered per head of population).

Unfortunately, the problem of inequality is getting worse. Rising inequality in the OECD over 25 years has resulted in a cumulative loss of GDP of 8.5% (Stanley et al. 2018). Today, almost one in six working age Australians relies on welfare for all or part of their income, thus considerable government revenue is spent on this support (Cowan 2021). In addition to this direct transfer of funds, the formal welfare support sector is large, as are the community support and volunteer sectors.

There is thus another important class of benefit potentially available from enabling those at risk of mobility-related social exclusion to engage more fully in society: these benefits are what we call **social exclusion externality benefits**. As noted, those who are socially excluded commonly have a higher risk (than those who are more included) of being unemployed, of having poorer health (mental and physical), of being less socially connected and some will be more likely to engage in crime and/or substance abuse. This report seeks evidence of such associations being linked with poor transport options. Increasing the social inclusion of such people can be expected to lower these wider societal 'external' costs – for example, lowering health system costs and increasing productivity. To the extent that existing bus services, or bus service improvements, support greater social inclusion, as the Melbourne research by Stanley and Hensher (2011) demonstrates is the case, then there may be additional benefits that should be attributed to these services/improvements, in the form of reduced social exclusion externalities.

Such external benefits are occasionally recognised in general terms as resulting from better public transport services (e.g., PTEG 2013) but we are not aware of any research that has systematically measured their magnitude

in a context of public transport service provision and/or improvement. For example, if bus services in outer Melbourne or a Victorian regional town were improved, what might this do to reduce mobility-related social exclusion and what **flow-on reductions in social exclusion externalities** (lower societal costs) might be expected? How significant might these flow-on benefits be, relative to currently estimated benefits from bus service improvements?

Exploring the answers to such questions is the intent of this report. In pursuing such matters, it also takes the opportunity to revisit the way some of the direct benefits of public transport (bus) services/service improvements, with which the prospective flow-on (external) consequences are associated, are measured and valued. This re-visitation uses a new way of seeking to quantify benefits, including direct user benefits, via a pathway of measuring changes in subjective wellbeing and placing a monetary value on this change, using new research by Stanley et al. (2021a). It also takes the opportunity to re-visit the meaning of the social inclusion benefits of an additional trip undertaken by a person, derived from our earlier research (Stanley et al. 2011a, b, 2021a), arguing that the high unit values derived in that work may include some of the external costs of social exclusion.

The paper builds on over a decade of work that seeks to understand the drivers of social exclusion and disadvantage, on the premise that once the drivers are understood, and measured, then policy can target and change these drivers, in order to promote social inclusion and thereby reduce societal costs. The drivers include such factors as personal social capital and sense of community, household income, trip making and personality type. However, the ability to be mobile (undertake trips) also facilitates the achievement of many of the other drivers, both directly and indirectly. For example, if a young person can't get transport to school or higher education, then they are less likely to be employed and less likely to have an income that adequately meets their needs, risking poor mental and physical health and other indicators of disadvantage and exclusion from society's opportunities. Thus, the quality of land use planning and transport availability is critical to address social exclusion. The provision of a local bus network supporting a 20-minute neighbourhood is particularly likely to offer a solution to reducing many of the drivers of disadvantage and social exclusion.

Section 2 of this report describes the aim of the research. Section 3 summarises the Methods used to pursue this aim. Section 4 briefly overviews the costing framework that has been used to measure external costs, identifying two main pathways: material costs and quality of life or subjective wellbeing costs. Sections 5 to 8 of this report then go into detail on particular externalities of mobility-related social exclusion, using both a material costs perspective, as outlined in Section 4, and also some perspectives on wellbeing costs associated with the same phenomena. Section 5 discusses employment/ unemployment, Section 6 is about physical health externalities, Section 7 considers mental health and Section 8 discusses exclusion and crime. Section 9 discusses what are sometimes called 'community or neighbourhood effects' and how these might relate to mobility outcomes. Section 10 uses some of the findings from preceding sections to assess some major transport improvements, in a detailed case study approach, which explores the potential benefits from a number of different transport improvements. Section 11 sets out the report's main findings and conclusions.

Some progress in advancing the measurement of exclusion externalities is achieved in this report but the lack of hard data on dose-response relationships, as between new/improved services and wider societal outcomes, indicates the need for a concerted research program if the real scale of this external benefit opportunity is to be more fully understood. However, this said, this early work suggests that the social impacts of improved bus services is likely to be very high and further work on understanding this association would be of considerable value to individuals, society and to the government's budget bottom line. The paper concludes by suggesting that the inclusion benefits of additional trip making may pick up part of the exclusion externalities.

2. Project aim

This project aims to identify and measure the potential scale of social exclusion externality benefits that may be relevant to new/improved urban route bus services in cities like Melbourne, while contributing to understanding how the quantification of such effects can be achieved, closing a major gap in understanding of the prospective benefits from bus. Because this is new research in an international sense, the focus is kept to a small range of potential external benefit areas, these being potential savings attributable to increased employment levels, improved health (physical and mental) and a lower crime rate, within the context of reduced risk of mobility-related social exclusion. Some other potential social externality benefits are noted but not explored in any depth.

In the process of identifying and measuring such potential external benefits, the paper also has a supplementary aim, which is to explore whether taking a wellbeing-based lens to transport benefit identification and measurement can provide new insights into the potential scale of transport benefits, including benefits that accrue to users. This supplementary aim is more about user benefits and economic externalities than social exclusion externalities but the wellbeing focus that the report introduces provides an opportunity to revisit some aspects of transport user benefit assessment.

The intellectual foundation for a wellbeing focussed approach to user benefit assessment lies in the fundamental value judgement that sits behind cost-benefit analysis, the most commonly used evaluation tool to inform transport planning and policy development: that individual preferences should be normative for social choice (and hence used for appraisal to inform policy development) (Nash et al. 1975a, b). Wellbeing measurement has developed over the past few decades to the point where it can now be used to broaden the scope of matters included within monetised cost-benefit analysis (see, for example, van Praag and Ferrer-i-Carbonnell 2004 and the eminent persons report by O'Donnell et al. 2014). The present report provides some illustrations of such application, as applied to measuring the benefits of bus service provision/improvement, applications that emerged from the primary pursuit of associated flow-on externality benefits.

3. Methods

This project has four main stages. Stages 1 to 3 form the basis for approaching each of the externalities considered in this report, with Stage 4 bringing it all together.

(1) Literature review

Identifying the available international evidence base about mobility and social exclusion, the social costs of unemployment, health and crime and the relationship between these various outcome variables and mobility, particularly bus service levels. The literature review is intended to identify:

1. the state of the art in measuring the magnitude of the social externalities of disadvantage, as exhibited through unemployment, health (mental and physical) and crime (e.g., costs of crime and of operating the justice system); and
2. whether these societal costs might be related to bus service levels. The literature review encompasses both published literature on this aspect and communication with some of our international contacts to see whether there is any unpublished research that may be relevant.

(2) Cost the three chosen externalities

This step mainly involves researching government budget reports and research studies from organisations like the Productivity Commission and Australian Institute of Criminology, to identify any existing evidence about the scale of costs of unemployment, poor health and crime, their relationship with disadvantage and potential causal mechanisms, with a particular focus on mobility connections. This costing primarily encompasses material costs, since these are where most focus has been based.

The paper also looks for associations between these outcome areas and wellbeing, looking particularly for any monetisation of the wellbeing impacts. This leads to some reflection on how well material costs can represent the societal costs and benefits of exclusion, as currently applied, identifying some opportunities for better valuation practice.

(3) Explore cause-effect relationships

This is the main analytical part of the research, where we seek to identify associations between the three selected social externalities and the level of bus service provision. It first involves seeking to identify how improved bus services might affect mobility of those at most risk of mobility-related social exclusion, which is an area where some of the case study work is useful. Potential flow-on external effects of improving mobility opportunities are then considered, such as improved employment/productivity, better health and reduced crime levels. Where feasible, this impact has been linked back to the level of an individual trip, such that it can be used in service assessment and in-service upgrade planning and evaluation.

(4) Reporting

The final stage is documenting the research undertaken for this project, with a particular focus on explaining the additional quantified social benefits from new/improved bus services that have been identified in the study and how these might be used for improved transport planning and policy making purposes.

4. Costing social exclusion

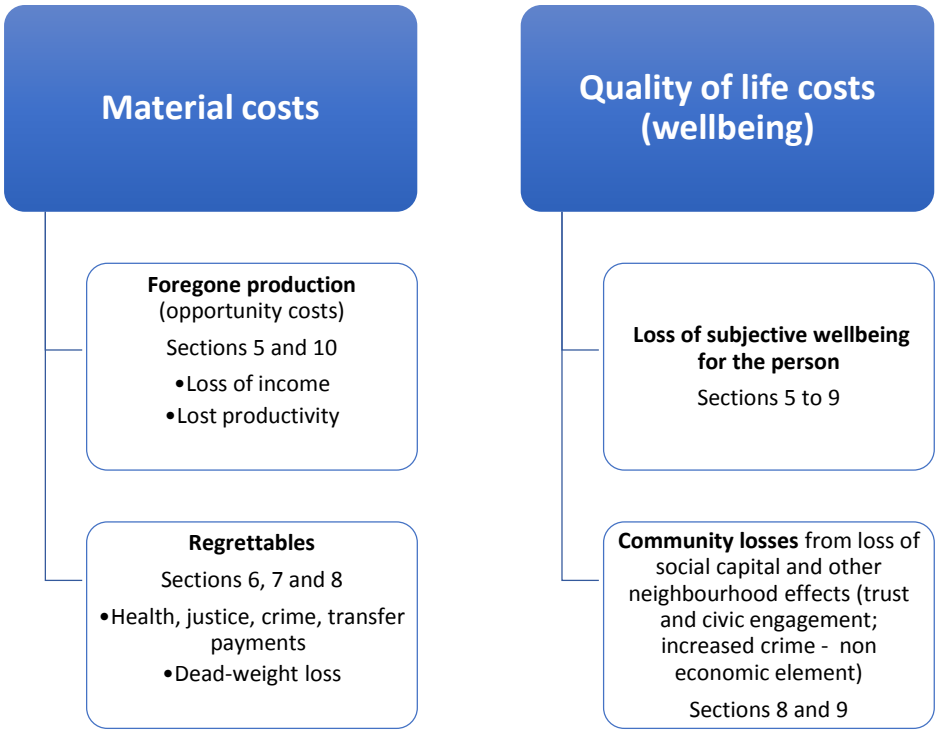
Quantifying the way that improved public transport (bus) services might reduce risks of social exclusion and, in so doing, lead to flow-on benefits from reduced exclusion externalities, requires an understanding of the costs of social exclusion, particularly those costs that might relate to mobility opportunities. These provide the starting quantum whose reduction is being explored in this paper.

Productivity Commission staff have produced a useful working paper that discusses social disadvantage in Australia and explores how to assess the costs of such disadvantage, both to the individual and to the wider society (McLachlan et al. 2013). That paper makes the important economic point that the cost of disadvantage (or exclusion) should be assessed in terms of *avoidable costs*, which are estimated as the difference between actual and potential outcomes. Estimation of avoidable costs involves developing a realistic counterfactual. Thus, in the absence of a particular intervention to reduce disadvantage, how would the future for target groups and the wider society have developed, with respect to the outcome variables of interest, these being unemployment, physical and mental health and crime in this paper? This is necessarily speculative in many ways but is also unavoidable if one is seeking to identify the prospective societal value of reduced social exclusion.

The general approach to costing disadvantage discussed in McLachlan et al. (2013), which draws on OECD (2011), is summarised in Figure 4.1. It distinguishes between what it calls *material costs* and *quality of life costs (wellbeing).* Material costs include costs of foregone production, partly measured by the loss of income to the individual (e.g., from being unemployed) but also including potential scale effects economy wide (agglomeration economies), which are relevant externalities for the purposes of the current paper. Figure 4.1 also indicates where various costs are discussed in this report.

In terms of **material costs** of **foregone production,** most quantitative work looks at the direct costs from loss of income. These costs, net of transfer payments such as unemployment benefits (a regrettable in Figure 4.1), accrue to the disadvantaged/excluded person, rather than being an externality, and it is worth noting that employment/unemployment is one of five indicators of exclusion risk used by Stanley et al. (2011a). One relevant externality that associates with changes in employment is the potential agglomeration economies from increased economic scale and density. These are explored in this paper in Section 10, via a Sydney case study.

Figure 4.1: Framework for costing disadvantage
(drawing on McLachlan et al. 2013)



Material costs called **regrettables** in Figure 4.1 are public (governmental) expenditures that could have been avoided if social exclusion/disadvantage had been prevented or reduced. They include costs on the health and justice systems and transfer payments (including the deadweight cost of taxes needed to cover such payments). The transfer payment component is largely a matter of the incidence of the costs in question, as between the benefit recipient and the wider tax paying public, but the deadweight cost is a net economic loss. Context specific avoidable regrettable costs are externalities of disadvantage.

This report focusses on external (regrettable) costs of poorer health, both physical and mental, and of a higher crime rate. For example, Brown et al. (2012) estimated that governmental (regrettable) expenditure on health could be reduced by $2.8 billion if the social determinants of the health gap between the top and bottom income quintiles could be removed (2008 prices). The key challenge for the present paper is identifying reasonable dose-response relationships between improved mobility opportunities and levels of particular regrettable expenditure, with a focus on health and crime, to narrow such costs down to potentially avoidable costs that might be associated with bus service provision/improvement. This is done most successfully herein for some aspects of physical health.

Quality of life costs include losses of subjective wellbeing of the disadvantaged person. These are usually not externalities, but they provide a more comprehensive indication of the scale of the costs of social exclusion or social disadvantage to the at-risk person, costs which might be reduced or avoided by improved mobility opportunities. There are good reasons to argue that subjective wellbeing measures are highly relevant for cost-benefit analysis (CBA), given CBA's intended emphasis on how individuals assess changes in their welfare. New research by the current authors and colleagues has enabled estimation of the value of changes in wellbeing, using three different conceptions of wellbeing (Stanley et al. 2021a). That work is relevant to measuring some of the more subjective costs associated with exclusion, the resulting measures providing a more comprehensive assessment of the costs of exclusion to the at-risk person than material costs alone. For example, material costs *per se* do not encompass matters like pain and suffering associated with being a victim of crime. Wellbeing measurement and valuation may be able to assist here.

To illustrate how such matters are approached in this report, Section 5 discusses the issue of employment gains associated with improved public transport services and suggests relevant values using a material costs approach, based on earnings. It then looks at the potential monetary value of improvements in subjective wellbeing associated with an unemployed person moving into full-time employment. It shows that the value of the gain in subjective wellbeing is greater than the earnings gain associated with moving to FT employment, which suggests a need to broaden current evaluation procedures to recognise this added benefit. Agglomeration benefits are also relevant here and are considered in Section 10.

McLachlan et al. (2013) also recognise community or neighbourhood level costs that may be linked with disadvantage or exclusion. These are clearly externalities, which can arise, for example, if social exclusion or disadvantage erodes social capital, leading to adverse impacts on neighbourhood quality and/or other valued social outcomes, such as safety perceptions, with many people in the community affected. McLachlan et al. (2013) were not able to value this external cost. This issue is considered in Section 9.

5. Improved employment outcomes

This section of the report first discusses improved employment outcomes from a **material cost perspective** (Sections 6.2 and 6.3) and then introduces a **wellbeing perspective** (Section 6.4). The discussion on the wellbeing approach is reasonably detailed since it involves some approaches that will not be familiar to some readers. This structure, of discussing material costs first then relevant wellbeing costs, is used in each of Sections 5 to 8.

5.1 Measurement from a materials cost perspective

We follow the general approach outlined in the Productivity Commission Staff paper (McLachlan et al. 2013) by seeking to measure economic costs of lower material living standards in terms of:

1. the opportunity costs of foregone employment income, and flow-on effects; plus
2. expenditure on 'regrettables', which can be thought of as governmental expenditure that, in the absence of disadvantage, would not be preferred.

This section discusses the opportunity costs of foregone employment. Section 5.2 then introduces potential flow-on effects on productivity, through agglomeration benefits, which are measured in case studies in Section 10.

Measuring the economic cost of foregone employment because of disadvantage, or social exclusion, mainly requires estimation of lower labour force participation/ higher unemployment and underemployment that arises because of the disadvantage of interest, in the present case this being poor mobility opportunities. This cost falls on the individual, somewhat offset by transfer payments, if applicable. There is inevitably a requirement for averaging to estimate such costs at the individual level but this need not detract from the value of the relevant estimation. Such costs can then have a flow-on effect to lower productivity, both through lower human capital accumulation but also through loss of potential agglomeration economies. McLachlan et al. (2013) suggest that the latter are difficult to measure but progress identifying agglomeration economies in recent years has improved prospects for relevant quantification, as discussed in Section 5.2.

We focus here on identifying costs at the individual level of reduced involvement in the labour force. Table 5.1 shows a number of trend indicators of average weekly earnings (AWE) in Australia as at November 2020. These range from a low of $1050.60 per week for females (all employees) AWE to a high of $1886.00 for male (full-time) adult AWE. If bus services/service improvements lead to increased aggregate employment levels, then the potential average benefit per additional employee might be approximated by numbers like those indicated in Table 5.1, net of transfer payments (unemployment benefit). However, it seems likely that these averages will overstate the earnings of those at most risk of social exclusion, who might be more likely to be unskilled and younger or older in age, suggesting lower average earnings. The numbers in Table 5.1 are thus likely to be over-estimates of income gains from reduced unemployment.

Table 5.1 Average weekly earnings: Australia – trend (November 2020)

Category	$ per week
Males	
Full-time adult average weekly ordinary time earnings	1804.20
Full-time adult average weekly total earnings	1886.00
All employees average weekly total earnings	1526.60
Females	
Full-time adult average weekly ordinary time earnings	1562.00
Full-time adult average weekly total earnings	1582.30
All employees average weekly total earnings	1050.60
Persons	
Full-time adult average weekly ordinary time earnings	1711.60
Full-time adult average weekly total earnings	1769.90
All employees average weekly total earnings	1280.30

Source: Australian Bureau of Statistics (2021).

5.2 Productivity effects

An extensive body of research has emerged on transport and economic development, much of it with a focus on cities and productivity growth, parts looking at the transport influence thereon. Research on agglomeration economies, arising from economic density has been central. The origins of such productivity gains have been understood for some time, summarised by Puga (2010) as sharing, matching and learning.

In urban settings, productivity increases (agglomeration externalities) of 3% to 8% from doubling city size (Rosenthal and Strange 2004) and 4.5% to 6% from doubling employment density in a city (Ciccone and Hall 1996, Ciccone 2002) are widely cited. The meta-analysis by

Melo et al. (2009) suggests a mean elasticity value of 3% across all its reviewed studies, with considerable variation between studies. Graham and Gibbons (2019), in a more recent study, find an unweighted elasticity value across 47 international studies of 4.6%. More recent research has tended to strengthen support for the lower end of the elasticity range, as issues such as firm selection and sorting have been recognised. Relative output increases in service industries, particularly knowledge-intensive industries, many of which tend to concentrate in CBDs and other urban hubs, are typically at the high end of the elasticity range. Melo et al. (2009) for example, report an elasticity of urban agglomeration for service industries of about 8%. The Sydney case studies undertaken for the present research, which are reported in Section 10, use an elasticity value of 2.1, based on Hensher et al. (2012), which is a relatively conservative value, based on the evidence cited herein. In more formal language, this value is the elasticity of productivity with respect to effective economic density.

Evidence of the existence of agglomeration economies is then suggestive of opportunities for external benefits from transport initiatives that can enhance the effective economic density on which such agglomeration economies depend, such as by extending catchment scale, with resulting benefits being additional to direct transport user benefits (subject to measurement approach).

Estimation of potential agglomeration benefits in transport appraisal requires three steps, as outlined by Graham and Gibbons (2019):

1. calculate a connectivity metric to represent agglomeration (or effective density);
2. estimate elasticities of productivity with respect to agglomeration; and
3. quantify the agglomeration impacts arising from transport schemes using the values derived from steps 1 and 2.

The ITLS MetroScan model includes a procedure for estimating agglomeration economies associated with transport improvements. The four major Sydney assessments undertaken by ITLS for this project (and to assist the NIEIR research project for BusVic), which are a major road upgrade, major rail upgrade and two major bus upgrade projects, include estimation of prospective agglomeration benefits from the transport improvements in question, explaining the measures of effective economic density and agglomeration elasticity used in the assessments. The results of that analysis are set out in Section 10 of this report. They show that doubling bus service frequencies across most parts of the middle and outer suburbs in Sydney is likely to deliver:

- small agglomeration economies, that are equivalent in value to about 2% of the cost of providing the added services; and
- increases in total employment levels, at the rate of about 15 jobs per $1m of expenditure on bus service increases.

The analysis shows, however, that major increases in bus service densities that are based only in outer suburbs may have small negative effects on agglomeration and total employment, through the encouragement that is provided to less dense settlement patterns. The Sydney case study on doubling of bus service frequencies in Sydney's outer west suggests agglomeration diseconomies equivalent to around 5% of the costs of the service expansion in this case, with reduction in total jobs across Sydney region at a rate of about 15 jobs per $1m of service costs, the mirror of the gains predicted if the service increases are more broadly based. In short, there is potential for improved bus services to support agglomeration economies and job growth, provided those service improvements are broadly spread across a city like Sydney and, by extension, Melbourne. Potential employment effects of how transport improvements are funded would also need to be recognised if the potential employment benefits (value of increased jobs) are counted.

5.3. A subjective wellbeing approach to the costs of unemployment

This section considers employment-related costs associated with a lower quality of life. The Productivity Commission staff paper (McLachlan et al. 2013) suggests that measuring the social costs from a lower quality of life is more challenging than measuring the economic costs, pointing out that measures of subjective wellbeing are increasingly being used for this purpose:

> *"Lower life satisfaction can be the result of outcomes such as lower engagement in work and other meaningful activities, poorer health, poorer relationships and less control over personal circumstances. These outcomes are more likely for people who are currently experiencing disadvantage (indeed they may be the source of the disadvantage), and for people who have experienced severe disadvantage in the past. A number of studies find that people experiencing these types of outcomes have significantly lower levels of life satisfaction or happiness."*

(McLachlan et al. 2013, pp. 24-5)

McLachlan et al. (2013) provide a timely reminder that such outcomes can lead to flow-on consequences for the wider community, such as when neighbourhood level costs result (e.g., disadvantage can reduce bridging social capital that leads to reduction in networks and opportunities in the neighbourhood in which people live).

There are a number of studies that suggest that the cost of unemployment to the unemployed person is substantial and greater than foregone income. This is not surprising, because of the potential effect of unemployment on matters like self-esteem and feelings of lack of control and helplessness (Goldsmith et al. 1996) and because unemployment may affect expectations of (discounted) lifetime earnings. Life satisfaction studies commonly show this result. The lower levels of income from government benefits also reduces the opportunities for any children in the household, thus risking adverse psychological impacts, such as feelings of shame, and the establishment of intergenerational disadvantage. An example of the latter may be inability to afford the cost of a school excursion or personal computer.

In an Australian setting, Dockery (2005) shows the importance of work, and the quality of that work, for a young person's sense of wellbeing. Carroll (2007) showed that unemployment is associated with lower life satisfaction and that, compared to the effect of income on life satisfaction, the unemployment effect is large. Using three waves of data from the Household Income and Labour Dynamics Survey in Australia (HILDA), Carroll found that, to compensate for the adverse effect of unemployment on life satisfaction, men would need to be given an additional $A42,100 and women an additional $A86,300 (~2002 prices). He argues that the large amount of income compensation needed to offset the effect of unemployment on life satisfaction partly reflects the relatively small effect of income on life satisfaction. Carroll points out that his monetary values for Australian men are considerably smaller than overseas findings for Germany and the US but that values for women are comparable to overseas results.

Our own research, with colleagues, on connections between mobility (trip making), social inclusion and wellbeing can be used to derive implicit values for the subjective wellbeing costs of unemployment (Stanley et al. 2011a, b, 2021). The data collected for that research included responses to a self-completed Victorian government household travel questionnaire. While this data is now over a decade old, its detail and depth mean that it remains incredibly rich for research. Some travel survey respondents were given the opportunity to opt into an additional comprehensive home-interview survey, which collected information on factors such as: social exclusion risk, social capital, connectedness to community, subjective wellbeing, psychological well-being, personality, transport problems, demographics and household composition. People at high risk of social exclusion tend to not complete travel diaries, so a supplementary survey targeted such people at welfare agency offices, given that social exclusion was a key focus of the research. This ensures a reasonable sample size of employed and unemployed people, with which to investigate the costs of unemployment in terms of subjective wellbeing.

This paper uses the Melbourne sample of 784 respondents. Table 5.2 summarises some participant characteristics, comparing them to the population of Melbourne Statistical Division (MSD), where the surveys were undertaken. MSD data is from the 2006 Australian population census, about one year prior to the time of the surveys. Some data comparisons are not available. Survey participants had relatively lower involvement in full-time employment than the Melbourne labour force as a whole, lower educational attainment and higher unemployment, primarily because of the study interest in social exclusion. The sample population had a much higher proportion of youth (15-17 years of age) than Melbourne, because one intent of the study was to enable consideration of mobility challenges of young people. Survey respondent numbers aged 18-39 are well below the Melbourne proportion but representation of those aged 40 or over is comparable between the survey sample and the wider Melbourne population. The numbers of survey respondents who were born overseas was lower than for Melbourne as a whole (by 13 percentage points).

The survey gathered detailed data for three conceptions of wellbeing:

- *evaluative or self-assessed subjective wellbeing* – typically assessed using general life satisfaction or domain specific satisfaction measures (called subjective wellbeing in this paper);
- *affective wellbeing* – an assessment of positive and negative emotional states; and
- *eudaimonic wellbeing* – refers to living a life filled with purpose and meaning, a desire to grow and develop to one's full potential and being pro-social and other-focused.

This paper relies on the subjective wellbeing measure, for consistency with other research on the wellbeing costs of unemployment. *Subjective wellbeing* was measured using the Personal Wellbeing Index (Australian Centre on Quality of Life 2017). The Personal Wellbeing Index includes ratings for seven life domains (standard of living, health, achieving in life, relationships, safety, community-connectedness, and future security) and can be administered with an optional global satisfaction question asking: "Thinking about your own life and personal circumstances, how satisfied are you with your life as a whole?" Each item was rated on a scale from 0-10, with 0 representing "no satisfaction at all" and 10 representing "completely satisfied".

For the present study we used the global satisfaction question as the indicator for wellbeing of various sub-sets of the study sample but also included domain specific satisfaction with life scores for health, what you are achieving, personal relationships and feeling part of the community. These provide some insights into the key elements of the overall measure. Some of the satisfaction measures are based on a smaller sample, because youth were not asked those questions.

Table 5.2 Respondent characteristics from Melbourne Metropolitan Survey			
Characteristic	**Sample number (N=784)**	**Sample (Labour force) (%)**	**Melbourne Statistical Division (Labour force) (%)**
Labour force status			
- Full-time	142	18.1 (37.0)	42.2 (64.9*)
- Part-time and/or Casual	168	21.4 (43.8)	19.2 (27.7*)
- Unemployed	74	9.4 (19.3)	3.7 (5.3*)
- Retired	158	20.2	10.4**
- Study	131	16.7	5.8**
- Home duties	45	5.7	10.4**
Age			
- 15–17	134	17.1	4.8
- 18–39	201	25.6	40.7
- 40–64	301	38.4	38.7
- 65+	148	18.9	15.8
Education			
- Some primary school	4	0.5	na
- Finished primary school	4	0.5	na
- Some secondary school	339	43.2	na
- Finished secondary school	119	15.2	17.2
- Diploma/Certificate	160	20.4	22.3
- Degree	90	11.5	18.5
- Post–graduate	68	8.7	9.0
Country of birth			
- Australia	605	77.2	64.1
- English speaking country	68	8.7	15.2
- Non-English speaking country	111	14.2	20.7

Notes: * As a per cent of those aged 15 and over in the labour force. ** As a per cent of those aged over 65.
Sources: ARC study survey responses; Australian Bureau of Statistics 2006 Census of Population and Housing General Community Profile, *Cat. 2001.0*. Canberra: Author.

Table 5.3 shows how mean life satisfaction scores varied with employment status, with scores shown for satisfaction with life as a whole (PWI) and for the four domains noted above: health satisfaction; satisfaction with personal relationships; satisfaction with feeling part of the community; and, satisfaction with what you are achieving in life. These four domain scores explain over 60% of the variation in the overall PWI score.

The mean PWI score across the total sample was 7.38, which is in accord with the usual score range for this measure. The highest mean PWI score, by employment category, was for retired survey respondents (mean 8.28; N=158) and the lowest, by a considerable margin, was for those who were unemployed due to disability, illness or injury (mean 4.63; N=49). Mean scores on all four domains were lower than the mean PWI score, particularly for satisfaction with feeling part of the community (mean = 6.42).

This is not surprising, given the weighting of the sample towards people who are more likely to be at risk of social exclusion. Mean satisfaction rating with personal relationships (7.34) was very close to the overall mean PWI score (7.38), suggesting that bonding social capital is likely to be relatively high among respondents, again in line with expectations for a sample geared more towards disadvantaged people.

Retired respondents not only had the highest mean scores for PWI but also the highest mean scores for satisfaction with personal relationships, feeling part of the community and with what they were achieving with life. However, their mean satisfaction with health (6.84) was lower, again not unexpected and a good indication of the reliability of the data. Those undertaking unpaid voluntary work had the highest mean score for satisfaction with what they are achieving in life (7.86), which is positive, but sample size was only six people for this group, so little weight can be placed on the mean score.

Table 5.3 Subjective wellbeing and employment status – mean scores					
Employment status	**Satisfaction with life as a whole: PWI (N=784)**	**Health satisfaction (N=784)**	**Personal relationships satisfaction (N=650)**	**Feeling part of community satisfaction (N=650)**	**What you are achieving in life satisfaction (N=650)**
Employed FT	7.62	7.34	7.39	6.14	6.95
Employed PT	7.69	7.13	7.69	6.85	7.42
Employed casual	7.65	7.23	7.65	6.67	7.38
Unemployed looking for FT work	6.02	6.27	6.21	5.50	5.27
Unemployed looking for PT work	6.89	7.00	6.92	5.83	5.83
Retired	8.28	6.84	8.27	7.23	7.49
Home duties/child care	7.42	7.33	7.09	7.09	6.78
Study	7.33	7.49	6.79	5.88	7.24
Unemployed due to disability, illness, injury	4.63	3.65	5.49	4.39	3.82
Looking after ill person or person with a disability	7.00	5.17	6.17	6.50	5.33
Unpaid voluntary work	7.43	6.57	5.57	6.29	7.86
Other	8.25	6.25	7.00	6.75	6.25
Averages (std deviations)	**7.38 (2.14)**	**6.88 (2.47)**	**7.34 (2.37)**	**6.42 (2.29)**	**6.79 (2.25)**

Note: FT = Full-time; PT = Part-time.
Source: ARC study survey responses.

Sample sizes are sufficient to examine the difference in subjective wellbeing (PWI) between employed and unemployed people. The mean PWI score for someone with FT employment in the sample (N=142) was 7.62, which was 1.60 units higher than the mean score for someone who was unemployed and looking for a FT job (N=56). Similarly, the mean PWI score for someone in PT employment (N=103) was 7.13, which was 0.80 higher than that for someone who was unemployed and looking for PT work (N=18). Strikingly, the difference in mean PWI score between someone who was employed FT (N=142) and someone who was unemployed due to disability, illness or injury (N=49) was a huge 2.99 points (out of a possible 10).

Independent samples t-tests show that the difference in mean PWI (satisfaction with life as a whole) scores between those employed full-time and those unemployed and looking for full-time work is statistically significant (<0.001), as is the difference in mean PWI scores between those employed FT and someone who was unemployed because of a disability (<.001). However, the difference in mean PWI scores between someone employed part-time and an unemployed person looking for part-time work was not statistically significant (0.264), partly due to the relatively small number who were unemployed and looking for PT work (N=18) and perhaps suggesting that those working part-time were not working many hours a week.

Stanley et al. (2011a,b) developed models to predict a person's risk of social exclusion, as a function of a number of explanatory variables. The measure of risk of social exclusion built on work by Burchardt and colleagues (2002). A person's risk of social exclusion was defined by five dimensions, with the threshold point that suggests a risk of exclusion noted in brackets, as follows.

- Household income (less than $A500 gross per week – 2008 prices) (this was the rate of aged pension in Australia at the time of the original research interviews).
- Employment status (not employed, retired, in education or training, undertaking care duties or doing voluntary work).
- Social support (not able to get needed help from close or extended family, friends or neighbours).
- Participation (did not attend a library, sport [participant or spectator] hobby or arts event in the past month.
- Political activity (not contributing to, or participating in, a political party, campaign or action group to improve social/environmental conditions, or to a local community committee/group, in the past 12 months.

Stanley et al. (2021a) have recently modelled risk of social exclusion as a function of those same variables but added subjective wellbeing (PWI) as an explanatory variable. Risk of social exclusion was expected to reduce with increases in Subjective Wellbeing, Bridging Social Capital, Bonding Social Capital, Sense of Community, trip making (trips being indicative of involvement in activities, suggestive of inclusion), household income, and if a person was aged 15-17. It was expected to be higher if they were part of the special sample, where a conscious effort was made to include those likely to be socially excluded who are frequently not participants in surveys. Personality was also tested in the model but was not significant, probably

because it was highly correlated with some of the other variables. Table 5.4 shows the relevant model from Stanley et al. (2021a), where all direction signs are as expected. Section 9 of this report discusses this research in greater detail, with a focus on issues of neighbourhood disadvantage.

Because PWI and household income (squared) are both significant in the model, the relative coefficients on these variables can be used to impute a monetary value to changes in subjective wellbeing. Stanley et al. (2021a) show that the resulting value is $124 at mean sample household income. In other words, increasing the PWI score of a person with household income equal to the sample mean by one unit is equivalent to giving them an additional $124 a day of household income. PWI in Stanley et al. (2021a) used the eight component measures of subjective wellbeing, as summarised above, and this is highly correlated with the overall measure of life satisfaction (which is one of the weight measures). We thus use the value of a change in PWI derived by Stanley et al. (2021a) to impute a value for the subjective wellbeing cost of unemployment.

Using this value, moving someone from being unemployed and looking for a FT job to being FT employed is equivalent to giving them an additional $72,500 of annual income (i.e., an increase of 1.60 units of PWI @ $124/day for 365 days a year) (2008 prices). The comparable sum for someone who is unemployed and looking for PT work moving to being employed PT is $36,230, although this value is less reliable than that for the FT employment value. If a more conservative approach is used and 250/days a year are assumed, rather than 365, the equivalent annual income equivalent sums are $49,660 for FT and $24,810 for PT.

Table 5.4 Modelling influences on risk of social exclusion: Model 1 (Subjective Wellbeing – PWI)

Attribute	Units	Ordered Logit	Generalised ordered logit
Constant		0.7575 (1.44)	1.3422 (1.49)
Personal Wellbeing Index	0-10	-0.2849 (-5.74)	-2.3430 (-4.66)
Sense of Community Low	1,0	0.4713 (2.94)	-1.3856 (-1.39)
Bridging Capital Low	1,0	1.3032 (7.40)	2.4071 (4.48)
Bridging Capital Medium	1,0	0.8071 (4.40)	1.4865 (3.34)
Bonding Capital Low	1,0	1.4657 (6.71)	2.6511 (5.28)
Bonding Capital Medium	1,0	0.4227 (2.67)	1.0316 (3.05)
Household Income Squared	$/day	-0.0018 (-6.20)	-0.0034 (-4.24)
Number of Trips	Number/day	-0.0733 (-2.59)	-0.1500 (-2.83)
Number Aged 15-17	Number	-0.8700 (-4.14)	1.8065 (1.15)
Special Sample	1,0	1.0510 (6.51)	2.0526 (4.80)
Threshold Parameters			
Mu (01)		2.0559 (21.61)	1.8404 (9.00)
Mu (02)		3.6648 (28.11)	1.0645 (6.31)
Mu (03)		5.6417 (23.22)	1.1494 (6.72)
Standard Deviations of Random Thresholds			
Alpha-01			1.4976 (2.51)
Standard Deviations of Random Threshold Parameters			
Personal Wellbeing Index			2.2246 (4.29)
Sense of Community Low			6.0946 (2.26)
Bridging Capital Low			5.2480 (1.82)
Number Aged 15-17			9.3889 (2.21)
Log Likelihood at Convergence		-834.79	-824.48
McFadden Pseudo-R^2		0.193	0.204
AIC/Sample size		2.213	2.199

Source: Stanley et al. 2021a, Table 3.

A second approach was taken to estimating the monetary value of the wellbeing increase if an unemployed person moves from looking for FT employment to being employed FT. Using the same data set as above, unit records for those who were employed full-time and those who were unemployed but looking for FT employment were extracted (N=198). Building on previous modelling insights, it was hypothesised that a person's subjective wellbeing (PWI score – as measured by the average of the 8 component measures) would be related to whether or not they were employed full-time or unemployed but looking for FT work (employed FT = 1; unemployed and looking for FT work = 0), household income, the level of social support the person perceived, their sense of community and the number of trips made per day, as an indication of activity engagement. The results for this model, Model 1, are set out in Table 5.5. The model explains a little over a third of the variation in PWI scores across the sample.[1] Sense of community and social support are strong contributors, both being significant at 1% level or better, as is household income. Employment is significant at 5% level, but number of daily trips is not significant. However, it is significantly correlated with support (1% level), thus making an indirect contribution.

A second model (Model 2 in Table 5.5) sought to build on the social capital/sense of community elements that appear very important in Tables 5.4 and 5.5 (Model 1), adding trust as an explanatory variable. The measure of trust was a combined measure of 'trusting people in your community' and 'trusting people in general'. Model 2 shows that trust is a very significant contributor to explaining variations in PWI scores, being significant at better than 1% level. However, including trust squeezes out social support as a significant variable in the model but sense of community remains strong. Employment and household income both remain significant contributors, albeit at a lesser level in the case of employment (10% level), with model 2 explaining a little over 40% of the variation in PWI scores across the sample group, some 6 percentage points more than model 1. Both models underline the importance of social capital and sense of community for subjective wellbeing, although the best way to approach social support and trust to build subjective wellbeing needs much more research, given the different results between the two models.

The main point of these two models is to enable an estimate of the value of moving someone from being unemployed but looking for FT work to being in FT employment. A little manipulation of the coefficients in models 1 and 2 enables this estimation. Table 5.6 sets out the results. The implied value of being FT employed, rather than unemployed and looking for FT work, is $87,900 in model 1 if 365 days a year are used for household income to convert daily household income to annual income, or $60,200 if 250 days are assumed (2008 prices). The corresponding values from model 2 are $80,240 and $54,960. These various values are strikingly similar to those estimated above using the Stanley et al. (2021a) estimates for the value of a unit change in PWI, which resulted in values which ranged between $49,660 and $72,500, for 250 and 365 days a year respectively. This is very encouraging.

Equally encouraging is that this set of monetary values of the subjective wellbeing benefits of moving from unemployment to employment are in the same ballpark as monetary values estimated by Carroll (2007) from a different Australian data set (the HILDA data) and for a few years earlier Carroll ~ 2003). As noted previously, Carroll found that, to compensate for the adverse effect of unemployment on life satisfaction, men would need to be given an additional $A42,100 and women an additional $A86,300, as noted above. ABS Average Weekly Earnings data suggests that earnings levels as used in the Stanley et al. (2011a, b) analyses are probably around 23% higher than for the Carroll (2007) paper, which would raise the Carroll $42,100 figure to $53, 000 (rounded) and the $86,300 to $106,000 (rounded) different. This range is consistent with the range shown in Table 5.6, the general concordance in values from the two different data sources and analytical approaches being encouraging.

Based on the various analyses reported above, we conclude that the subjective wellbeing value of someone entering FT employment, who has previously been unemployed and looking for FT work, is between $50,000 and $90,000 in prices from around 2008. Updating this range to November 2019 values by changes in average weekly earnings over the period (+40%[2]) increases the range to $70,000 to $125,000 (rounded), which we conservatively summarise as $90,000.

[1] VIF values indicate that multicollinearity is not a concern with the model, all values being <1.40. This also applies to model 2, in which all values are <1.75.

[2] Average Weekly Earnings, Australia, November 2020 | Australian Bureau of Statistics (abs.gov.au).

Table 5.5 Modelling subjective wellbeing (PWI) as a function of full-time employment or unemployment but looking for full-time work (N=198)				
	Model 1		Model 2	
	B (Std error)	Significance	B (Std error)	Significance
Constant	1.210 (.674)	.074	-.242 (.723)	.738
Employment	.512 (.229)	.026	.407 (.220)	.066
Support	.181 (.063)	.005	.048 (.068)	.478
Household income per day squared	0.000003497 (.000)	.005	0.000003045 (.000)	.010
Sense of community	.053 (.010)	<.001	.047 (.010)	<.001
Number of daily trips	.035 (.038)	.349	.034 (.036)	.348
Trust			.324 (.073)	<.001
Adjusted R^2	0.352		0.410	

Table 5.6 Estimating the value of the increase in subjective wellbeing from being employed full-time, rather than being unemployed and looking for full-time work (2008 prices)		
	Model 1	Model 2
Marginal rate of substitution between employment and PWI (MRS 1)	.512	.407
Marginal rate of substitution between household income and PWI at mean HHI (MRS 2)	0.002126206	0.001851387
MRS1/MRS2 at mean sample household income		
- 365 days a year	$87,900	$80,240
- 250 days a year	$60,200	$54,960

Table 5.1 suggested that Australian average weekly total earnings (persons) were $1769.90 in November 2019, which is around $92,000 per year, almost the same as has been estimated above using the subjective wellbeing approach. Netting out unemployment benefits reduces the increase in income, or benefit to the person entering FT employment, to around $75,000, with the savings in unemployment payments a benefit to Treasury (say $17,000 per person entering FT employment). The net earnings gain for the person moving from looking for FT work to being employed FT is around $75,000, or one-sixth less than the estimated value of the increase in subjective wellbeing (of around $90,000) for that person. However, this is likely to be an underestimate of the difference between the net increase in earnings to the person involved and the value of their increase in subjective wellbeing, since someone moving from unemployment to FT employment might generally be expected to earn less than average weekly total earnings (persons), perhaps considerably less.

We thus conclude that the value of the subjective wellbeing benefit to a person moving from unemployment to FT employment is substantially larger than the associated increase in salary/wages received by the beneficiary. This is not surprising, since the subjective wellbeing costs should pick up issues such as the stigma associated with unemployment. Carroll (2007) drew a similar conclusion. The values for wellbeing change are a more comprehensive indicator of the benefits of moving someone from unemployment, who is looking for FT work, to FT employment. The values in question are also similar to, if a little smaller than, values estimated for Japan by Kuroki (2013), as discussed in Section 8 (on crime).

5.4 Conclusion on increased employment

We conclude that a value of $90,000 (2019 prices) is a reasonable estimate for the value of the gain in subjective wellbeing realised by a person moving from being unemployed and looking for FT work to being employed FT. This amount is greater than the net increase in earnings realised by the person in question, which looks likely to be less than $75,000, probably considerably less since $75,000 assumes average weekly earnings are paid to the employee in question, which is probably an overestimate. The subjective wellbeing figure is a defensible estimate of the scale of benefits to the person who moves from unemployment and looking for FT work to being employed FT. Valuing the benefit of such a change in employment status solely by looking at the earnings gain to the person who moves to FT employment thus risks substantially underestimating the relevant benefit for evaluation purposes.

Savings in unemployment payments are a separate and additional benefit, to Government revenues, perhaps valued at around $17,000 per person moving from unemployment to FT employment. PT/bus service improvements that enable someone to shift from unemployment to employment are thus worth over $100,000 a year, per added job, valued as increased subjective wellbeing plus savings in government welfare payments. This is a potential additional benefit from the PT/bus improvement.

Transport improvements may also generate agglomeration (productivity) benefits, following increases in effective employment density that those improvements might stimulate. Section 10 of the report discusses agglomeration effects, which are external effects that may associate with initiatives to reduce exclusion.

6. Physical health

6.1 Context

PTEG (2013) sets out to make *The Case for the Urban Bus* in the UK. One of the sections in that report discusses the potential health and wellbeing benefits of urban bus. Four opportunities are identified:

1. the daily physical exercise associated with bus use, particularly the walk to and from bus stops;
2. being able to access health services and healthy food, by bus travel to appropriate locations;
3. bus travel as a way to support wellbeing, such as by connecting with others; and
4. bus travel as a means of supporting the independence of older people and persons with a disability. They might also have added supporting independence of young people within this point.

The focus in the current report is on the first of these opportunities but also with some acknowledgement of others.

Some authors looking at linkages between the built environment and health, such as Handy, Cao and Mokhtarian (2006, p. 55), do not mince words: *These days it is hard to miss that Americans are fatter than ever*. Australians also have a challenge with overweight/obesity, with 75% of men and 60% of women being overweight or obese in 2017-18.[3] Physical exercise is recognised as likely to be beneficial for health issues such as cardiovascular disease (CVD), coronary heart disease (CHD) and stroke, type II diabetes, hypertension, colon cancer, breast cancer, obesity, depression and all-cause mortality (WHO 2010).

Kelly, Murphy and Mutrie (2017) cite systematic review evidence that suggests that walking, in particular, has a beneficial effect on CVD, CHD, type II diabetes and depression. Public transport (bus) use involves incidental exercise. This section of the report explores potential health benefits associated with the walking involved in using public transport. The importance of this opportunity has recently been recognised in Australia, where the Transport and Infrastructure Council's *Australian Transport Planning and Assessment Guidelines – M4: Active Travel* includes estimated benefits from walking, which can be associated with public transport use (TIAC 2016). Those Guidelines are used later in this section of the report.

The exploration in the current report is primarily in terms of potential benefits through reduced prevalence of overweight/obesity conditions but with some broadening through reference to TIAC (2016).

6.2 Health costs

The Australian Institute of Health and Welfare (AIHW) suggests that Australian health costs totalled $195.7 billion in 2018-19, with spending on hospitals ($79b) the largest, followed by spending on primary health care ($66b).[4]

These aggregate expenditures, however, shed little light on avoidable expenditures that might be associated with improved health of particular population groups, such as disadvantaged people. In this regard, Brown et al. (2012) discuss the social determinants of health and estimate potential benefits if inequities could be removed, including savings to the health system. To develop this estimate, they explore some implications of removing the health gap between the most and least disadvantaged Australians, considering both self-reported satisfaction with health and health conditions. They conclude that, by removal of this particular health gap (Brown et al. 2012, p. vii):

> - *"500,000 Australians could avoid suffering a chronic illness;*
> - *170,000 extra Australians could enter the workforce, generating $8 billion in extra earnings;*
> - *annual savings of $4 billion in welfare support payments could be made;*
> - *60,000 fewer people would need to be admitted to hospital annually, resulting in savings of $2.3 billion in hospital expenditure;*
> - *5.5 million fewer Medicare services would be needed each year, resulting in annual savings of $273 million;*
> - *5.3 million fewer Pharmaceutical Benefit Scheme scripts would be filled each year, resulting in annual savings of $184.5 million each year."*

[3] Overweight and obesity: an interactive insight, Prevalence - Australian Institute of Health and Welfare (aihw.gov.au).

[4] Health and Welfare Expenditure Data - Australian Institute of Health and Welfare (aihw.gov.au).

These numbers suggest a large number of beneficiaries receiving small benefits and a small number of beneficiaries receiving large benefits, with:

- the Medicare and PBS savings averaging just over $40/beneficiary (in the price levels used in the analysis), with over 10 million annual beneficiaries;
- close to $40,000 savings per hospital admission avoided, involving 60,000 annual cases; and
- around $70,000 in benefits per additional job produced (2008 values), including both the earning component and the reduced need for welfare payments, with 170,000 annual jobs involved. The income component of the $70,000 figure, which accounts for a large proportion of this sum, is based on differences in income between those with poor health and those with good health, which will be (and is) smaller than the income gain from changing from unemployment to employment as estimated in Section 5 of the current report (for comparisons where both estimates are based on ~2008 income values). The two estimates of income gain are thus not measuring the same thing and their relativities are as expected. Section 5 also included valuation of the gain in subjective wellbeing associated with a person moving from being unemployed and looking for a fulltime job to being employed fulltime.

These numbers provide useful per capita indicators of potential external benefits from health improvement attributed to removing the particular health inequity that was explored, although McLachlan et al. (2013) argue that not all these costs are avoidable with respect to disadvantage. They suggest, instead, that they provide an upper bound estimate of savings if health levels of disadvantaged people could be improved, as analysed.

Brown et al. (2012) also find that removing this health inequity would result in:

- an estimated 370,000 to 400,000 additional disadvantaged Australians in the 25-64 years age group seeing their health as good (presumably being mainly aligned with the 500,000 who could avoid suffering a chronic illness); and
- as many as 120,000 additional socio-economically disadvantaged Australians being satisfied with their lives.

The main interest in the current paper is not with health per se but with to what extent health might be improved by enhanced mobility opportunities. This requires drilling down into health data to identify potentially avoidable health conditions, the costs of such conditions and to then form a view about whether improved mobility opportunities might be a feasible way of improving health. As pointed out by TIAC (2016), there are two main types of health-related benefits that can flow from active travel:

1. morbidity and mortality benefits; and
2. reduced health system costs.

The Australian Institute of Health and Welfare (2019a, b, 2020) talks about the burden of disease, encompassing dying prematurely (the fatal burden = mortality) and living with poor health (non-fatal burden = morbidity), using disability adjusted life years (DALYs) to combine the two components. One DALY represents one year of healthy life lost, whether through dying prematurely (= years of life lost, or YLL) or from living with an illness or injury (= years lived with a disability, or YLD). TIAC (2016, p. 32) points to the relevance of this concept for assessing the benefits of active travel:

> *"Willingness to pay benefits [of active travel] are typically based on the potential of active travel, as a form of physical activity to reduce the number of disability adjusted life Years (DALYS) lost as a consequence of inactivity."*

AIHW (2019b) indicates that Australia lost 4.8 million years of healthy life (DALY) in 2015-16, split almost equally between dying prematurely and living with an illness. The Australian Institute of Health and Welfare (AIHW 2020), in its discussion of health equity, considers potentially preventable hospitalisations (PPHs). PPHs are classified as vaccine preventable conditions, acute conditions and chronic conditions, the latter being defined as *long lasting conditions that may be preventable through lifestyle change but are also manageable in the community health care setting to prevent worsening of symptoms and hospitalisation* (AIHW 2020, p. 136). Conditions such as diabetes complications, heart failure, chronic obstructive pulmonary disease (COPD) and asthma are included in this category.

Some 38% of the 4.8m DALYs lost in 2015-16 was regarded as preventable, by reducing exposure to modifiable risk factors. The most important risk factors identified by the Australian Institute of Health and Welfare (AIHW 2019b) as contributing to these preventable conditions were tobacco use (9.3%), overweight and obesity (8.4%), dietary risks (7.3%), high blood pressure (5.8%) and high blood plasma glucose (including diabetes) (4.7%). Overweight and obesity (9.1% of YLL and 7.7% of YLD)[5] and physical

[5] The source of the percentages in this sentence is AIHW (2019b), Table D2.

inactivity (3.6% of YLL and 1.5% of YLD) are noteworthy for those interested in mobility opportunities for health improvement.[6]

The Australian Institute of Health and Welfare (AIHW 2019b) suggests that the PPH rate for type II diabetes complications was three times as high in low socio-economic areas as in high socio-economic areas, reflecting health inequities and providing a clue as to where the largest unit benefits might be sought.

6.3 Obesity and overweight

It is in the area of chronic conditions (lifestyle related) that mobility improvements might be most relevant to improved health outcomes. Increased active travel, including the walk legs of a bus trip, for example, could be one way of contributing to such benefits, being recognised as one way of achieving the minimum recommended 30 minutes a day (150 minutes a week) of moderate exercise (Swift et al. 2014). Obesity is an area that has received considerable focus in recent years, in terms of incidence, prevention and health costs, and is one area for assessing links to improved mobility.

Body mass index (BMI) is used to categorise weight conditions, as follows:

Underweight	BMI<18.5
Normal	BMI 18.5-24.99
Overweight	BMI 25 or more
Pre-obese	BMI 25.00-29.99
Obesity Class I	BMI 30-34.99
Obesity Class II	BMI 35.00-39.99
Obesity Class III	BMI 40 or more

AIHW reports that, in 2017-18:[7]

- Australia had the 6th highest proportion of overweight or obese people aged over 15 among 22 OECD countries;
- one in four children and adolescents (aged 2-17) were overweight or obese;
- 33% of men and 30% of women were obese, with 75% of men and 60% of women being overweight or obese in that year; and
- 38% of adults in the lowest socio-economic areas were obese, compared to 24% in the highest areas.

The data supporting the AIHW information shows that the proportion of the Australian population aged 18 or more that was obese nearly doubled between 1995-96 and 2017-18. This is clearly a national problem, with socio-economic/spatial inequities, and it is getting worse.

An approach based on PWC (2015)

PWC (2015) provides an informative analysis of the costs associated with obesity, pointing out that 27.5% of Australians were obese in 2011-12 (BMI 30 or more) and that this percentage was increasing (as reflected in the AIHW data above for 2017-18), with the severity of obesity also increasing. They projected that, without further intervention, 33.9% of Australians would be obese by 2025.

PWC (2015) estimated that obesity among Australians aged 18 and over added $8.6b to Australian health costs in 2011-12 (in 2014-15 prices), with $3.8b in direct costs (including pharmaceuticals $1.4b and hospital care $1.2b) and $4.8b in indirect costs ($3.8b being foregone tax revenue). Of the $8.6b cost in 2011-12, some $6.6b was estimated to be Commonwealth Government cost. The projected increase in prevalence and severity of obesity was projected to cost Australia $87.7b over the period to 2025. However, costs associated with reduced wellbeing and foregone earnings were not included in the analysis, making these estimates very conservative. For example, PWC (2015) develops an estimate for the mortality/ morbidity costs of obesity of $47.7b in 2011-12, based on a value of statistical life (VOSL) of $183,000 and a risk factor for high body mass of 8.4%. They also identify a further $11.8b in potential foregone earnings, implying that the total costs of obesity in 2011-12 might be more like $60+b, rather than the $8.6b very conservatively assessed in their report (PWC 2015). Wellbeing costs are not included in PWC (2015) but are recognised as relevant.

The average costs of obesity per person aged 18 or over in 2011-12 were estimated as follows, including only the particular costs attributed to obesity by PWC (2015):

- Obesity Class I = $1470;
- Obesity Class II = $1950; and
- Obesity Class III = $3180.

The projected increased costs of obesity over the period to 2025 can be manipulated to suggest the marginal costs (per person) of increasing obesity, over a decade or so. These can be estimated as follows (rounded):

- Obesity Class I = $40,200;
- Obesity Class II = $49,900;
- Obesity Class III = $79,100; and
- All classes = $49,200

[6] Within the chronic conditions, AIHW (2020) indicates that congestive cardiac failure had an average cost of $9798 per PPH (with PPH = 60,964 and total cost of $597m in 2015-16), COPD was $7930/day (PPH = 31,726 and $252m cost) and hypertension $3021 (PPH = 9990 and cost of $32m in 2015-16). Across all chronic conditions, the average daily cost per PPH was $7217.

[7] Overweight and obesity: an interactive insight, Prevalence - Australian Institute of Health and Welfare (aihw.gov.au).

In short, preventative measures that avoid one person from becoming obese are projected to deliver savings of $40,000 to $80,000 in present value terms over a decade, the higher figures being associated with the most severe cases of obesity. Across all obesity levels, an average figure of around $50,000 per person who avoids becoming obese results, over a decade (2014-15 prices and 2011-12 health costs). These numbers are conservative, as noted above.

Unfortunately, PWC (2015) does not extend to assessing the potential impact of increased physical exercise, such as walking to/from a bus stop, on obesity levels. However, they do include a case study that assumes 157,400 obese people a year, spread across the obesity range, participate in a program that leads to 5% weight loss in the first year, with some recidivism thereafter. Over a 10-year period this is estimated to deliver benefits of $1350m, at a cost of $670m (mainly for GP visits associated with the program), for a benefit cost ratio of 2.

The implied average health benefit per program participant (beneficiary) per year across the decade is $860, excluding wellbeing costs. Allowing for different health benefits for those with differing obesity levels, and recognising that benefits extend beyond one year, the effective value of benefits after a decade is around $7300 for a person in Obesity Class I who reduces their obesity level over the decade, $7500 for someone in Obesity Class II and $9700 for someone in Obesity Class III. The assumed pattern of weight loss (5% in first year, with varying paths beyond) is important in driving these results but is based on referenced evidence. These values are low compared to the implied marginal future health costs estimated above (of between $40,000 and $80,000), suggesting that they are very conservative.

PWC (2015) also notes that depression is often associated with obesity, but that teasing out the marginal costs of depression attributable to obesity, beyond what might already be covered in the VOSL costs, is complex, as is determining causality. They note, however, that there are likely to be costs of depression that are not adequately reflected in VOSL, albeit unquantified. Similar conclusions are reached in PWC (2015) about costs of discrimination experienced by obese people.

The approach of TIAC (2016)

TIAC (2016) directly addresses the potential health benefits of walking, as a form of active travel, separating out mortality/morbidity benefits and benefits of reduced health system costs. The PWC (2015) analysis is primarily related to the health system costs, so the TIAC (2016) approach is broader and results in a higher relevant cost. TIAC relies on prior research that suggested 6.6% of DALYs and health system costs were attributable to physical inactivity[8], concluding that the annual per capita cost of inactivity in 2010 (and 2010 prices) was $2131, comprised of $1382 mortality and morbidity costs and $749 health system costs. These become potential benefits from increased physical activity.

TIAC (2016) reports that in 2011-12 some 20.5% of Australian adults were inactive, 36% were insufficiently active and only 43.5% were sufficiently active. Taking account of these proportions, the costs of inactivity and the required levels of physical activity to meet health guidelines, TIAC (2106) estimates that the 2013 value of walking a kilometre was $2.77, of which about 35% was savings in health system costs and 65% mortality/morbidity benefits.

6.4 Walking and obesity: Adults

Mabire et al. (2017) report a meta-analysis of studies on the influence of age, sex and Body Mass Index on the effectiveness of walking briskly for obesity management in adults. The mean BMI of the samples included in their analysis was 32.1 (i.e., within the Obesity Class I range). They note that the effectiveness of obesity management interventions is typically assessed using a 5% reduction in body weight and/or waist circumference over 3 months as a clinical outcome measure. They also note the recommended weekly 'dose' of 150 minutes of moderate intensity activity and focus on brisk walking as a means of achieving such activity.

Mabire et al. (2017) found an overall (pooled) average weight loss of 2.3 kgs and pooled reduction in BMI of 0.96 (kg/m^2, the way BMI is measured). This reduction was not correlated with the starting or base level BMI rating, indicating that it is relevant across the full range. They also found that women over 50 years showed a statistical but not clinical (i.e., 5%) reduction in BMI. The largest reduction in BMI was found for males aged <50 (mean reduction = 1.73). Men and women aged under 50 had much larger weight loss than those aged 50 and over.

This work suggests, prima facie, that bus users who walk to/from the bus stop are less likely to be obese than those who (say) drive to activities instead. The 0.96 reduction in BMI from 150 minutes brisk walking), compared to the Mabire et al. (2017) sample base BMI level of 32.1, is a 3% reduction, or less than the 5% starting reduction assumed by PWC (2015) for its case study discussed above, although that 5% reduction reduced somewhat over time. The small standard deviation in BMI measures across the various samples included in the Mabire et al. (2017) research (of 3.9), however, suggests low representation of people from Obesity Class III and poses questions about whether or not larger reductions in BMI (and associated greater health benefits) might be achieved if a person in Obesity Class III was to add 150 minutes of weekly walking to their routine).

[8] A little lower than used bny PWC (2015).

The American College of Sports Medicine (ACSM) has the following recommendations for physical activity (from Swift et al. 2014).

- Maintaining and improving health: 150 minutes a week.
- Prevention of weight gain: 150-250 minutes a week.
- Promote clinically significant weight loss: 225-420 minutes a week.
- Prevention of weight gain after weight loss: 200-300 minutes/week.

Swift et al. (2014) suggest that exercise programs that are undertaken in the absence of a program of caloric restriction are unlikely to achieve weight loss of more than 2 kgs, although this seems a little conservative in view of the Mabire et al. (2017) conclusion that 2.3 kgs was the mean pooled estimate from their meta-analysis. However, in line with the ACSM recommendations, Swift et al. (2014) report that obese individuals who have lost weight need a substantial amount of physical activity to maintain their weight loss and that larger increases in physical activity will increase the amount of weight loss that is achieved. More broadly, larger weight reductions result if physical activity is combined with caloric restriction but Swift et al. (2014) also provide an important reminder: that exercise training, regardless of weight loss, provides numerous benefits for those who are overweight and obese, such as reduced risk of cardiovascular disease.

6.5 Application to bus use

The preceding discussion is relevant to public transport service provision. Unpublished Melbourne research undertaken by Chris Loader, using VISTA data from 2012-18, shows that people who used public transport walked an average of 38 minutes a day, whereas people who did not use PT (largely car users) walked for only 9 minutes a day on average. The walking minutes of both PT users and non-users are skewed towards the (walkable) inner suburbs, where PT users walked for around 40+ minutes a day, as shown in Figure 6.1, reducing to around 32 minutes, on average, for those who lived more than 15 kms from the CBD. Non-PT users walked for only 5-9 minutes a day in the middle to outer suburbs, suggesting that encouraging these people to use PT would be one way of helping them achieve their 30 minutes daily walking (physical activity).

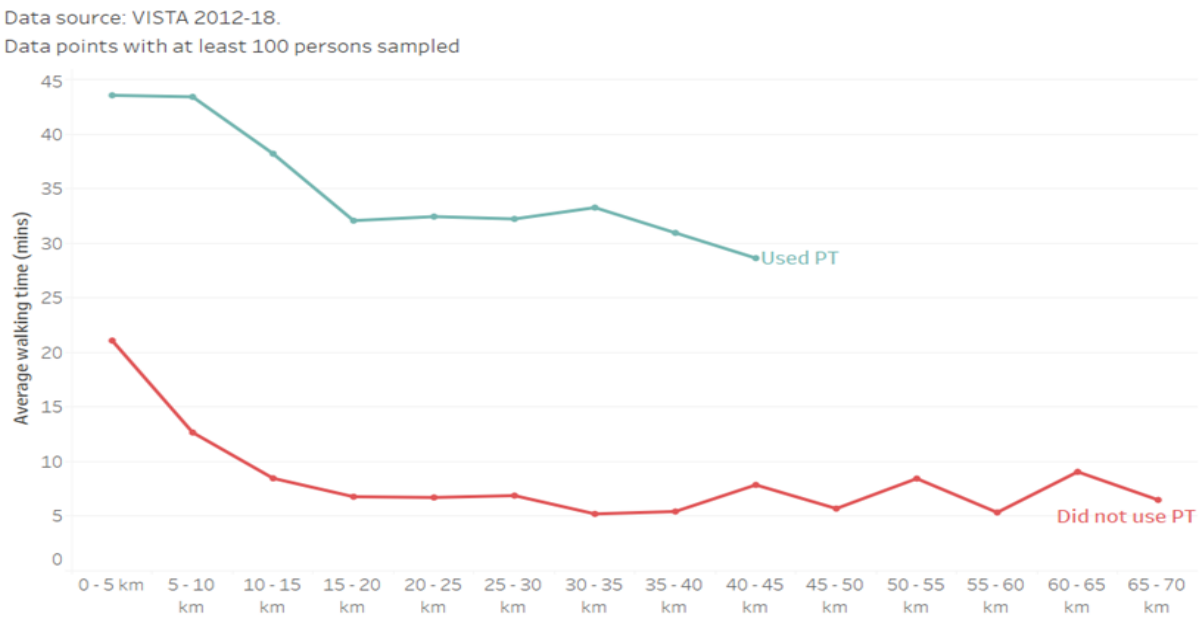
Given the interest of the current paper in bus, Figure 6.2 (also developed by Chris Loader) digs deeper into the walk distances of PT users, separating out those who used bus compared to those who did not use bus and, for bus users, showing whether they also used train or tram. Walk times for PT users who use bus at any given distance from central Melbourne are less than walk times for train/tram only users, which is not unexpected. It has long been known that people will walk further to access a faster mode and rail, with its own right-of-way, is faster than bus, which usually has to battle against other traffic in mixed traffic streams. Nonetheless, PT users who used bus as a stand-alone mode still typically get around 30 minutes daily walking time, or more than this if they live closer to the centre of the city. If they use bus and train or tram, then walk times mirror those for train/tram only users, up to 20-25kms residential distance from the CBD.

It is noteworthy that the PT curves in Figure 6.2 only extend to around 35 kilometres from the CBD. This is due to the threshold of 100 trips in VISTA being set for any given data point in the figure. The further from the CBD the poorer the PT service level, particularly bus, with a lower likelihood of VISTA sampling bus users within its survey frame. Combining all PT modes, as in Figure 6.1, provides at least 100 PT user observations out to 45-50 kms from the CBD but the same does not apply when PT modal data is required.

Figure 6.3 shows the average incidence of pre-obesity and obesity among the adult population across Melbourne in 2017. Only 1/31 LGAs (Melbourne City) had <25% of its adult population pre-obese in 2017 and 8 had over one third pre-obese, these being: Cardinia, Casey, Hobsons Bay, Hume, Moonee Valley, Moreland, Whittlesea and Wyndham. Ten LGAs had over 20% of their adult population rated as obese, these being: Brimbank, Cardinia, Casey, Frankston, Hume, Knox, Melton, Mornington Peninsula, Whittlesea and Wyndham.

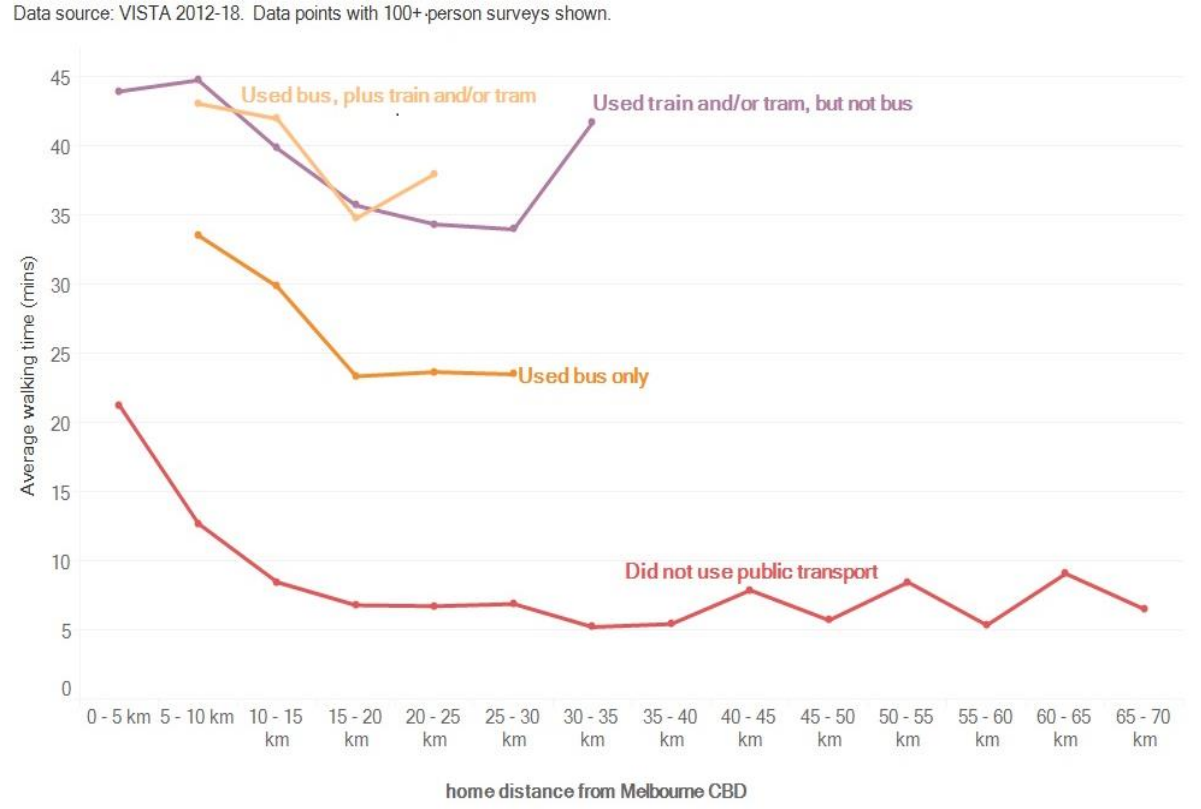
It is notable that the six outer urban LGAs with the fastest population growth rates (Cardinia, Casey, Hume, Melton, Whittlesea and Wyndham) are all in the grouping with the highest percentage of their adult population as obese. All except Melton are also in the group with the highest percentage of their adult population pre-obese. Melton's absence in the pre-obese group is most likely due to it having the highest percentage of obese adults of any of the LGAs. These fast-growing outer suburbs typically have the poorest bus service levels. Figure 6.4 shows that that few bus/tram stops in these areas meet a benchmark of 55 services a day, which would represent 20-minute headways for 18 hours a day, consistent with the Plan Melbourne idea of Melbourne as a series of 20-minute neighbourhoods (DELWP 2017).

Figure 6.1: Average daily minutes of walking: Greater Melbourne residents



Source: Chris Loader.

Figure 6.2: Average daily minutes of walking: Greater Melbourne residents, by whether public transport was used on survey day and home distance from CBD



Source: Chris Loader.

Figure 6.3: Pre-obese and obese adult population percentages by LGA: Melbourne 2017
(Source: Vic Population Health Survey 2017)

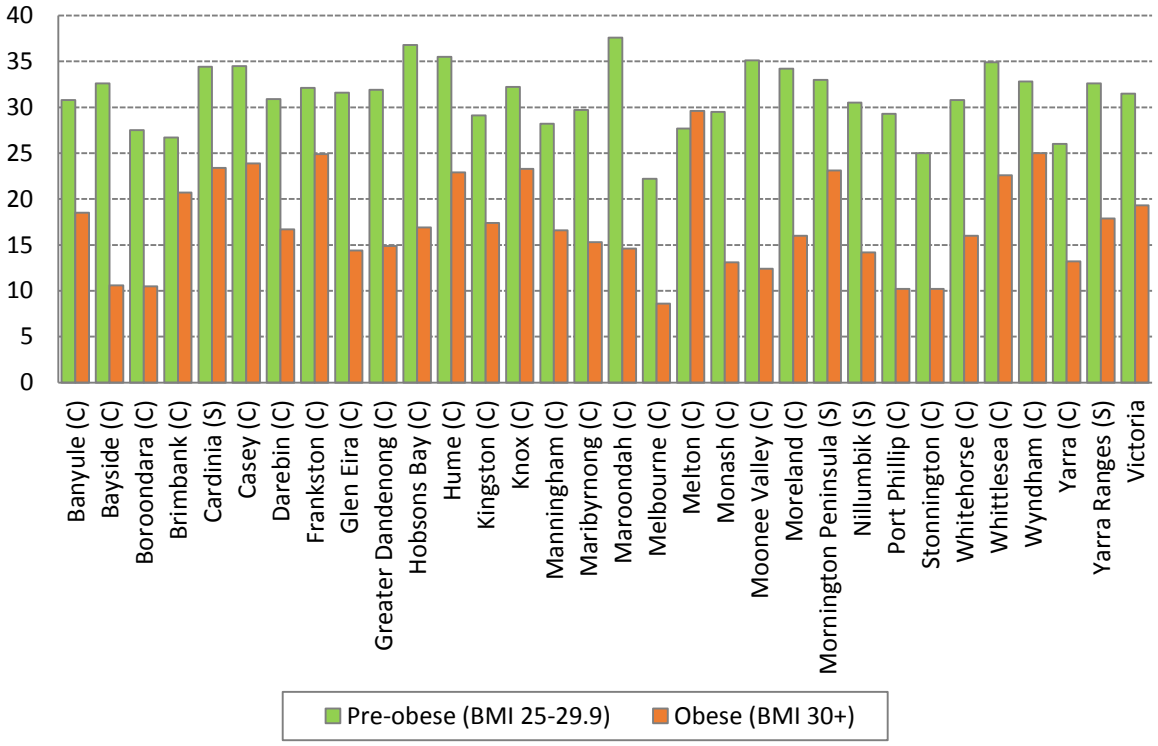
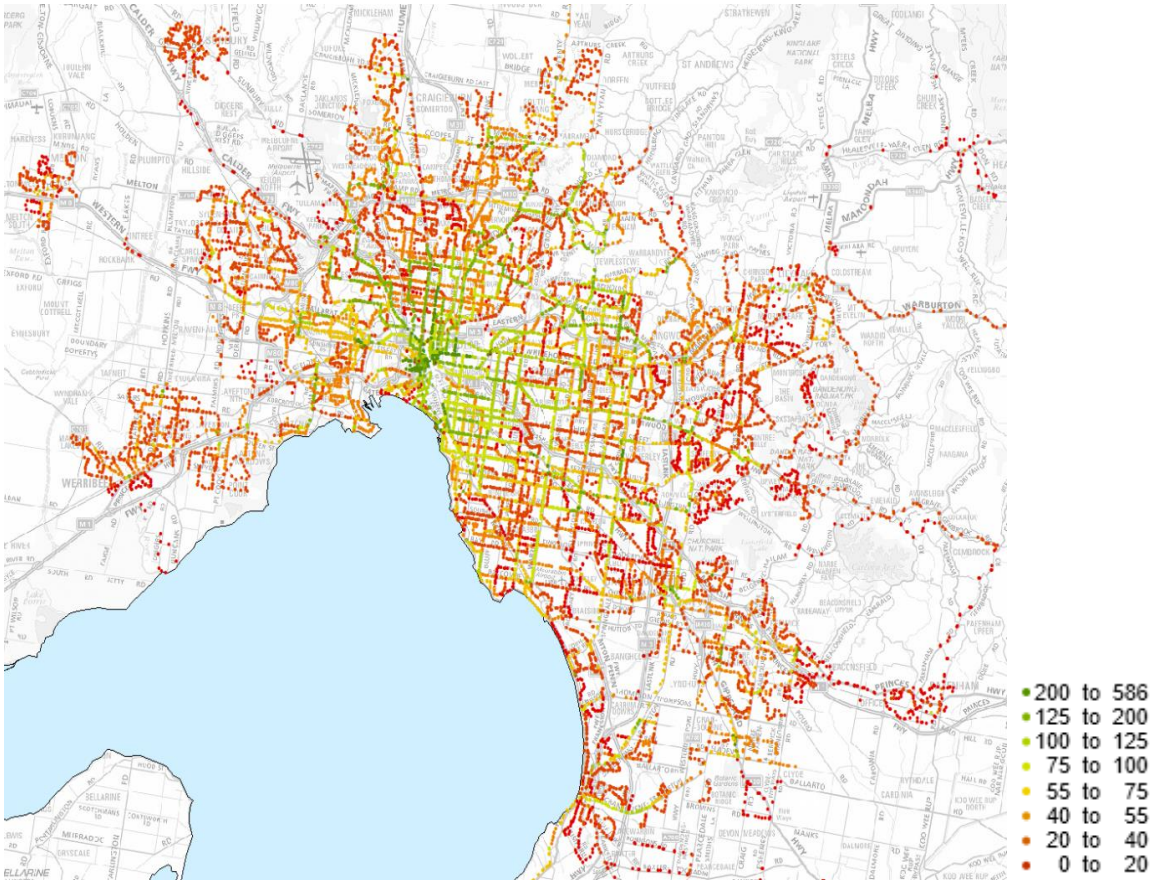


Figure 6.4: Melbourne's route bus and tram services: Services per stop per day on a typical weekday (each direction; 2019) (Source: PTV GTFS feed)

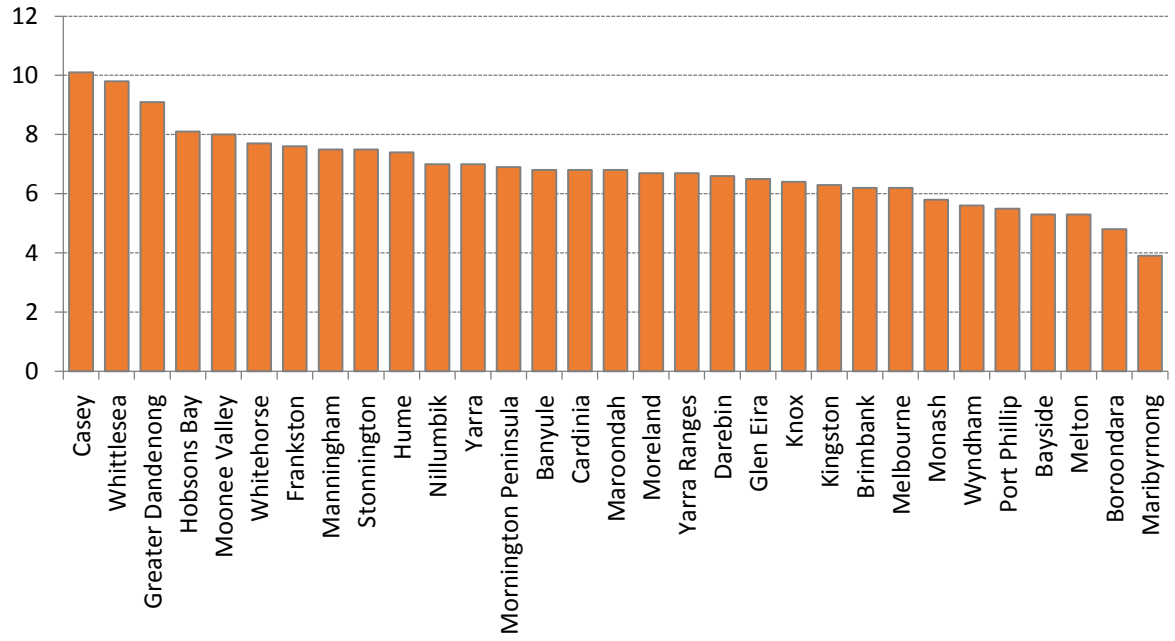


Brain, Stanley and Stanley (2018) showed the impact of Melbourne's rapid population growth from 1992-2017 on income earning capacity and on some social outcomes. The research found that residents in the six fastest growing outer suburbs of Cardinia, Casey, Hume, Melton, Whittlesea and Wyndham, went backwards, relative to the state as a whole over the 1992-2017 period, in terms of capturing income from economic activity. That paper also showed, using 2016 census data, that as travel times from an LGA to central Melbourne increased, population and job densities decreased, median house prices declined and open space per resident increased but:

- capital stock per person declined, the proportion of higher educated people declined, the proportion of jobs that are high-tech declined and LGA productivity declined;
- trust in others declines;
- the proportion of people living near public transport declined and public transport use for the journey to work also declined;
- car use increased for the journey to work and the proportion of commutes that are longer than 2 hours increased; and
- reports of heart disease and obesity increased.

The data in Figure 6.3 illustrates that evidence with respect to obesity, as discussed above. Figure 6.5, from Brain et al. (2018), shows how the reported incidence of heart disease (relevant to physical activity) is also typically higher in the outer growth LGAs (4/6 are in the top half by reported incidence).

Figure 6.5: People reporting heart disease, by LGA (%)



Source: https://www2.health.vic.gov.au/about/reporting-planning-data/gis-and-planning-products/geographical-profiles.

How then might the potential contribution of bus use to reduced risk of adult obesity be calculated? We start from the evidence that bus carries around 120 million trips a year in Melbourne and assume that each bus user has an average daily walk time of 30 minutes or more, as illustrated in Figures 6.1 and 6.2. Mabire et al. (2017), discussed above, suggested that achieving the guideline 150 minutes physical activity (PA) a week would reduce BMI by around 3%. Meeting that guideline for 52 weeks a year would require at least 7800 minutes of exercise (150*52=7800). Achieving 7800 minutes of walking time could be achieved by taking 520 bus trips, or 10 per week.

PWC (2015) set out a case study that suggests that the value of a ~5% reduction in BMI averages around $860 per adult in 2014-15. Updating this figure to 2019, by the increase in CPI, produces a figure of ~$926. Achieving the guideline PA level might deliver 3% of the 5% BMI reduction used by PWC (2015), or around 60% on an assumption of linearity in contribution. Commenting on the association between walking and all-cause morbidity (not just obesity), Kelly et al. (2017) suggest that the greatest relative improvements in all-cause morbidity from increased walking will be for those currently doing less than 100 minutes walking a week, suggesting a non-linearity in the walking/health response relationship at the

low exercise end. This may make an assumption of 60% as discussed above somewhat conservative. Applying the 60% PA guideline achievement rate to the value of $926 suggests that 7800 minutes of walking to/from bus would be worth $556. Spread over 520 bus trips, an implicit value of $1.07 per trip results. If a conservative 50% of all Melbourne route bus trips were made by adults, then this would have a value of around $64.2m as a measure of health benefits of route bus services, solely in terms of the health benefits of reduced overweight/obesity, these being largely savings in government health costs. This is very small relative to the $8.6b total estimated avoidable costs of obesity from PWC (2015), which suggests that it is a conservative estimate. For example, PWC (2015) acknowledges that its cost estimates make no allowance for reduced wellbeing or foregone earnings. The current report looked at employment values in Section 6.

An alternative way to valuing the health benefits of walking associated with bus trips is to use the value of walking from TIAC (2016). This includes mortality/morbidity benefits, which account for ~65% of walking benefits, as well as health system cost savings (~35%), so might be expected to be about three times the size of the estimate based on the PWC (2015) case study, which focussed on estimating health cost savings but recognised the existence and importance of mortality/morbidity costs. TIAC (2016) estimated that the 2013 health benefit of walking was worth $2.78/km, based on the national spread of activity/inactivity levels. TIAC seems to assume a 5kph walking speed, such that 30 minutes walking time associated with bus trips would imply 2.5 kms walk distance, commonly spread over 2 bus trips (i.e., one return trip). Two bus trips would thus be worth $2.78*2.5 = $6.95, in 2013 prices, or $3.48 per trip. Because these benefits are externalities, we see no reason to apply a rule of half for valuing additional trips. Updating this to 2019 values for mortality/morbidity benefits (by CPI) and health care costs (by health spending) produces a walking benefit value of ~$4.05 per bus trip.

One of the authors is an active walker. who considers that a 5kph walking speed, as used in the TIAC costing, may be too high for many walkers, such as some older bus users and people who are actively talking to another while they walk, with 4kmh being more suitable for many bus access/egress walks. The Melbourne data shown in Figure 6.2 suggests around 25-40 minutes walking per day for a bus user, compared to 7-8 minutes for someone who did not use PT. Thus, additional bus trips can be assumed to add around 30 minutes to daily walking time. At an assumed 4 kph walking speed, this implies 15 minutes additional walking time per additional bus trip, or 1 km walk distance per trip. Updating the TISC value of $2.78/km, which was in 2013 prices, to 2019 prices, produces a walking value of ~$3.25/km[9], which is also $3.25 per bus trip, based on the walking speed assumptions adopted herein.

A walking benefit value of $3.25/bus trip is almost exactly 3 times the benefit scale estimated previously by use of the PWC (2015) case study example ($1.08/trip), which is very reassuring. The $3.25/adult bus trip estimate based on TIAC (2016) walk values includes mortality/morbidity benefits which are not part of the PWC (2015) case study unit values. Given that the mortality/morbidity benefit component accounts for 65% of total walking benefits per km in the TIAC work but are not part of the benefit value imputed from the PWC (2016) research, we conclude that valuation of the health benefit component is highly consistent as between PWC (2015) and TIAC (2016).

Given the standing of the TIAC Guidelines more broadly, and the recognition by PWC (2015) that mortality/morbidity costs of inactivity are real and important, unit benefit value based on the TIAC methodology is seen to be appropriate. As used herein, the TIAC benefit per kilometre has been extrapolated to a benefit per adult bus trip, based on VISTA data on Melbourne walk times and an assumption about walk speeds of 4 kmh. This results in conservative benefit values of $3.25 per bus trip or additional bus trip, a little lower than the ~$4.05 which seems to be implied by TIAC's own work (which we believe is based on walk speed/distances that are too higher than assumed here).

Using the unit value of $3.25/bus trip in 2019 prices, if 50% of all Melbourne route bus trips are made by adults and the activity/inactivity profile of bus users is in line with the rest of the population (in the absence of an available bus service as a base case), then Melbourne's route bus services would have **an implicit annual health benefit value of around $195 million, associated with the incidental walking for those bus trips**. This is substantial by any reckoning.

By way of confirmation of the broad scale of this valuation, it is noteworthy that the Queensland Government's Gold Coast Light Rail Stage 3A Business Case estimated walking benefits of $37.6m in PV terms (IA 2019) for that one project, implying around $3m annually in undiscounted terms. This is from a single project which is only estimated to increase the overall PT corridor mode share from 5.3% to 5.9% (IA 2019). This underlines the importance of recognising and measuring the health benefits of PT services and service upgrades. Section 10 includes estimated walking benefits for substantial increases in Sydney route bus service frequencies.

[9] Health expenditure increased at a faster rate than implied in this update but earnings and CPI grew more slowly. The $3.25 is considered a reasonable rounded estimate (weighted).

6.6 Physical health and subjective wellbeing

Valuation of the external health-related benefits from the physical activity involved in walking to/from a bus stop, as discussed above, depends substantially on a case study from the PWC (2015) work, which includes only health-system cost savings (largely reduced cost of GP visits), and on TIAC (2016), which adds mortality and morbidity considerations. It is also worth exploring whether this same physical activity might also be amenable to valuation via a pathway that explores the impact of the relevant walking on the subjective wellbeing of the walker, which would be expected to lead to larger values than either of the previous two approaches. Such wellbeing benefits, if identifiable and measurable, are not an externality, since this is about valuing the benefit of the exercise in question to the exerciser. However, to the best of our knowledge, any such benefit is not currently measured and included as a monetisable benefit by those who evaluate the merits of bus service provision and/or upgrading, except insofar as part of the wellbeing impact might be reflected in mortality/morbidity effects.

Humphreys, Goodman and Ogilvie (2013) explored the relationship between active commuting and physical and mental health, in a case study based around Cambridge UK. After adjusting for other physical activity, they found an association between physical wellbeing and time spent in active commuting but found no such relationship for mental health. Recognising the 150 minutes benchmark, they used 4 active commuting bands in their research: 0-29 minutes active commuting/week; 30-149 minutes/week; 150-224 minutes/week; and 225 or more minutes a week. They found the association between active commuting and physical wellbeing increased as the amount of active commuting increased. Importantly, they concluded that, although the regression coefficients they estimated for the association between active commuting and physical wellbeing were below the threshold for individual clinical significance, the differences they estimated *may still have important population-level significance in settings such as Cambridge with a high prevalence of active commuting* (Humphreys et al. p. 138). However, their work did not extend to monetisation of the wellbeing impacts and the measures of wellbeing that they used are not the same as those available to the current authors for monetisation purposes.

Ngamaba et al. (2017) undertake a meta-analysis of the association between physical activity and subjective wellbeing. Across 29 studies they found a medium scale mean effect size ($r = 0.347$; $p<.001$) for the association between health status and subjective wellbeing, with a slightly larger mean effect size when SWB was measured as life satisfaction ($r = 0.365$). They suggest that life satisfaction is a better measure of subjective wellbeing than happiness, since life satisfaction better captures health status. However, their research does not suggest how particular changes in health status will impact life satisfaction.

Wicker and Frick (2017) use Eurobarometer data (cross-sectional data from 28 countries) to analyse the effect of different intensities of physical activity and of meeting/not meeting WHO guideline levels of physical activity on the subjective wellbeing of adults aged 18-64 and those aged 65 or older. Subjective wellbeing was measured as life satisfaction on a 1-4 scale, with a mean value of 3 (~8.25 on a 0-10 scale measure of life satisfaction, or slightly higher than the usual Australian value, the difference being partly linked to the differences in scale opportunities (4 possible answers compared to 11)). However, this scale difference is not critical. They found that, for those aged 18-64, walking (minutes and days a week) and vigorous activity (minutes/days) significantly added to SWB, whereas moderate activity had a negative impact. They also found that those in both age groups meeting the WHO guideline of 150 minutes moderate intensity activity a week reported significantly higher SWB, compared to people who did not meet the guidelines.

However, there are concerns about some of the implications of the coefficient values estimated by Wicker and Frick (2017). For those aged 18-84, the marginal effect of walking on SWB was estimated at 0.0695 (5% significance level), suggesting that walking 150 minutes a week might increase SWB by about 10 units, which seems totally implausible with a dependent variable that has a maximum value of 4. Also, the coefficient on meeting the WHO guideline for moderate activity for those aged 65 or more is 4.116, which again exceeds the maximum value of the dependent variable, suggesting that 150 minutes a week is all you need for high wellbeing if aged 65 or more! With the dependent variable in their research having only 4 possible values, and these values being ordered rather than strictly continuous, logistic regression would have been a preferable basis for the analysis than multiple regression. The research supports the role of walking and physical activity in enhancing SWB but there are challenges in using its coefficient values to suggest the scale of impact that walking might have on SWB.

Panza et al. (2019) examine the effect of physical activity at various levels of intensity on subjective wellbeing in healthy US adults, noting that previous studies on associations between physical activity and wellbeing sometimes report mixed results. They measure what they term psychological wellbeing (score range = 0-110; mean value = 89.0; SD = 14.2), which is broader than life satisfaction, encompassing also indicators of affect and eudaimonic wellbeing. However, their reporting of results does not enable these three components of wellbeing to be disentangled (this is unfortunate, because the current authors have estimated monetary values for changes in positive affect and in some elements of eudaimonic wellbeing, as well as for subjective wellbeing). Panza et al.

(2019) find (among other things) that objectively measured (by accelerometer) light intensity physical activity is associated with higher psychological wellbeing and negatively associated with depression and that sedentary behaviour is negatively associated with psychological wellbeing. Moderate intensity activity was also associated with improved psychological wellbeing. However, while the analysis supports the idea that walking to/from a bus stop is likely to improve wellbeing, it is not helpful in terms of predicting the scale of cause-effect change for life satisfaction, the indicator that is being used in the current report, of a given amount of walking or changes therein. Psychological wellbeing effect sizes for the psychological wellbeing impact in Panza et al. (2019) are typically relatively small (<0.2) but this may be a reflection of the fact that their sample was of 'healthy' adults.

In short, there is evidence of a *positive association* between walking, particularly brisk or moderate intensity walking, and subjective wellbeing but not sufficient evidence to predict a cause-effect relationship with any confidence. This needs more research into the various relationships, with a stronger focus on *causation*, as distinct from *association*. The available evidence base is not currently strong enough to attempt monetisation of subjective wellbeing benefits from walking that is associated with public transport travel.

6.7 Physical activity and obesity: Children

Brown et al. (2019) provide a good overview of studies examining strategies for reducing the risk of childhood obesity, drawing on the results of 153 randomised control trials. They conclude (Brown et el. 2019 np):

> *"Interventions that include diet combined with physical activity interventions can reduce the risk of obesity (zBMI and BMI) in young children aged 0 to 5 years... However, interventions that focus only on physical activity do not appear to be effective in children of this age. In contrast, interventions that only focus on physical activity can reduce the risk of obesity (BMI) in children aged 6 to 12 years, and adolescents aged 13 to 18 years."*

The mean reduction in BMI from physical activity, found from 14 randomised control trials involving children aged 6-12, compared with control, was 0.10kg/m^2 and, for adolescents aged 13-18 years, was 1.53 kg/m^2.

Wyszyńska et al. (2020) present the findings from a task force from the European Childhood Obesity Group and the European Academy of Paediatrics, including presenting the consensus of these groups on the role of physical activity in the prevention of excessive body weight and providing age-appropriate recommendations for physical activity, plus recommendations for school-based interventions.

They conclude that children and adolescents should have at least 60 minutes/day of moderate to vigorous physical activity, including a variety of aerobic activities, pointing out that half the children in Europe do not meet this guideline. Activity beyond 60 minutes was expected to provide additional health benefits. Among their recommendations to parents, guardians and teachers was that they should encourage children and adolescents to incorporate active transportation and recreation, physical education, or planned exercise within their daily routines. They note that increased physical activity in childhood is correlated with lower risks of cardiovascular diseases, type 2 diabetes, and increased life expectancy in adulthood. Importantly, they also point out that increased PA has many benefits for children, from improvements in lipid and glucose homeostasis to improved endothelial function and that these health benefits usually occur independent of changes in BMI. In short, changes in BMI may not be a good measure of the benefits of increased PA for children but, for many children, increasing PA may be sufficient to prevent the onset of obesity.

Wyszyńska et al. (2020, n.p.) also point out that:

> *"It has been suggested that 2.5 h of moderate PA per week compared with no activity was related to a reduction in mortality risk of 19%, whereas 7 h a week reduced mortality risk by 24% … There is substantial evidence that being physically active has positive effects on psychosocial well-being, cognitive outcomes, and academic performance (e.g., grades and test scores), as well as mental health..."*

As noted above, one in four Australian children were overweight or obese in 2017-18. Black, Hughes and Jones (2018) estimate the health care costs of obesity among children aged 6-13 in Australia, using a sample from the Longitudinal Study of Australian Children. They consider only costs incurred by the Australian Government through non-hospital Medicare services and the Pharmaceutical Benefits Scheme. They find that, among children aged 6-13, being obese added $103 a year to health costs (as defined) in 2015, while being overweight adds $63. Multiplying these costs out to the total population of children aged 6-13, they conclude that the total costs of childhood overweight/obesity to the Australian Government in 2015 was $43m.[10]

Larouche, Mitra and Waygood (2019) look at the relationship between transport and children's physical wellbeing through three different lenses:

1. intrinsic (i.e., the physical exercise involved in travel itself);
2. access to destinations that facilitate physical exercise; and

[10] zBMI scores are used in their analysis (standard deviations for BMI,) since obesity (for example) is defined as when the BMI is above 2 standard deviations from the mean for sex and age.

3. externalities such as traffic accidents, air quality, noise and barrier effects.

They conclude that a child receives positive wellbeing-related benefits from active and independent travel. However, their focus in relation to the intrinsic link between transport and physical exercise is focussed on walking and cycling per se, rather than on public transport and the incidental exercise associated therewith. They conclude the following (Larouche et al. p. 34):

> *"… the evidence consistently indicates that those children who walk or cycle to/from school are more physically active than those who do not. While cycling is likely to provide more immediate benefits such as improved cardiovascular fitness, regular walking is important for the formation of long-term healthy habits."*

By implication, the walking associated with PT (bus) use will also be beneficial but was not discussed in their paper.

Larouche, Mitra and Waygood (2019 point to the trend for declining independent mobility of children, from influences such as the growth of auto dependency and associated low density development patterns, together with parental safety concerns about children travelling independently in the presence of motor vehicles. Waygood (2019) notes that independent mobility for children is associated with finding friends, building social bonds and strengthening a child's sense of belonging. Such considerations suggest that the independent mobility provided by public transport is increasingly important for children and young people, but the research evidence does not currently permit this to be taken through to quantification of bus use/wellbeing relationships.

This research all points to bus use, involving a walk component, being beneficial for child wellbeing, both intrinsically through the associated incidental exercise and also through the access to destinations that is facilitated, including the independence associated therewith.

However, this research has not developed to the point at which one could project monetary benefits associated with such effects with any confidence for children or young people. Some of the studies cited above might be used to suggest that walking associated with PT could provide about half the daily walking/exercise needed by a child and this might reduce health costs by perhaps $70-120 a year, which would suggest the exercise (walk) value of a bus trip to a child is of the order of 10-15 cents a trip. This pales into insignificance compared to the value for an adult ($3.25 per trip) and is tenuous at best.

6.8 Conclusion

Section 6 identifies solid support for recognising the walking associated with a bus trip by an adult as having health benefits, which can be valued at around $3.25 per bus trip, based on values derived in TIAC (2016) Active Travel Guidelines, based on morbidity and mortality costs and health system cost savings, but with more conservative assumptions about walk distances and speeds than implied in the TIAC work. Walking associated with PT use also has benefits in terms of improved wellbeing, but the dose-response relationships are not solid enough at this time to put a reliable monetary value on those wellbeing benefits. This value suggests that the walking (physical health) benefits from Melbourne's route bus services are currently of the order of $200 million annually, in 2019 prices. Walking is also beneficial for the health and wellbeing of children and youth but there is not sufficient evidence at this time to put a monetary value on those benefits to these cohorts, or on the contribution that a bus trip may make to this health and wellbeing.

7. Mental health

7.1 Cost

There has been a major focus on mental health in Australia in recent years, with Victoria (for example) appointing a Royal Commission to report into this matter (Royal Commission into Victoria's Mental Health System 2021). Good mental health and wellbeing is not just the absence of mental illness, rather it is the ability to fully and effectively participate in society. The Commission estimated that the economic cost of poor mental health to Victoria is $14.2 billion a year.

In 2020, the Productivity Commission reported on its inquiry into Mental Health (Productivity Commission 2020). Some of the conditions that report considered were anxiety disorders, depressive disorders, personality disorders, bipolar disorder and schizophrenia. It noted connections between mental health and economic participation and productivity in Australia, pointing out that 'mental illness can impact all aspects of our life: relationships, home life, schooling, work, and social interactions' (Productivity Commission 2020, p. 4).

The annual cost of mental illness and suicide to the Australian economy was conservatively estimated by the Productivity Commission at $70 billion. They also recognise an additional avoidable cost of around $150b annually associated with diminished health and reduced life expectancy. Table 1 of the Commission Report (Volume 1), and Appendix H, outline the magnitude of various elements of these costs in 2018-19, as follows:

- mental healthcare and related expenditure = $15.5b;
- informal care provided by family and friends = $15.3b;
- income support payments related to mental illness = $10.9b;
- loss of participation and productivity = $12.2b-$39.1b;
- cost to economy (exc. the cost of diminished health and wellbeing) = $42.9b-$69.8b;
- cost of disability/premature death due to mental ill-health, suicide and self-inflicted injury = $150.8b; and
- income support payments for those with mental illness and carers = $10.3b.

The Commission argues that reform of the mental health system, along the lines it recommends, would deliver large benefits, including $18b annually in terms of improved quality of life and $1.3b annually through increased economic participation (people's capacity to work and earn higher wages), by both the at-risk people and carers. The Commission is not surprised at the relatively small size of the estimated benefits to the economy from mental health reform, pointing out that quality of life improvements are much larger in relative terms and that a number of potentially very large benefits could not be quantified in money terms, such as the benefits of reforms for those interacting with the justice system or the broader community benefits of improved mental health, both areas that are considered in this report.

The Commission suggests that 10 million Australians are at risk of mental illness, with 0.8m at severe risk, 1.2m at moderate risk, 2.3m at mild risk and 5.9m at some risk. If the $220b cost identified by the Commission is spread over 10 million at risk people, it implies an average cost of $22,000 per at risk person, with the range in cost obviously being very large at the individual level. By implication, if mobility improvements could help to improve someone's mental health, to the point of reducing treatment costs and providing associated benefits of the kind outlined by the Commission, there is potentially a substantial external benefit opportunity that could be quantified. However, we have found no cause-effect evidence in terms of the relationship between mobility and mental health. Some relevant insights are discussed in Section 7.2 but these are only preliminary starting thoughts for benefit assessment, as the research field is significantly underdeveloped.

The Victorian Department of Health (2015) reports connections between mental health and subjective wellbeing. People who reported having sought professional help for a mental health related problem were almost five times more likely to report low or very low subjective wellbeing. As the number of visits to a mental health professional increased, the level of wellbeing decreased. Victorian adults who had been diagnosed, at some time, with depression or anxiety were found to be four times more likely to have low or very low subjective wellbeing.

If significant associations could be found between mobility circumstances and depression and anxiety, then valuing changes in wellbeing (as per the approach that is discussed in Section 9 of this report) might be a pathway way by which to monetise some of the economic impact of improved mobility on this aspect of mental health (i.e., depression and anxiety). However, we have not found any quantitative evidence of connections between mobility, depression and anxiety, to which such wellbeing values could be applied.

7.2 Social connectedness and mental health

The importance of meeting and spending time with other people is increasingly being researched and documented. Such activities are described in a number of ways, such as social connectedness (related to a sense of belonging) or loneliness (being an absence of connection with people). Social support is achieved through these connections, as is sense of community and social capital. The absence of this social connection can lead to impacts such as loneliness, poor self-acceptance, loss of opportunities to develop capabilities, networks and personal growth, and poor mental and physical health, with the risk of perpetuating disadvantage (Australian Institute of Health and Welfare 2021, Frieling et al. 2018, Saeri et al. 2018). The New Zealand Ministry of Social Development has reviewed the subject of social connectedness, noting the importance of social connections for health and wellbeing (Frieling et al. 2018).

There has been a particular recent interest in research on loneliness. AIHW (2021) defines social isolation as "the state of having minimal contact with others" and loneliness as "a subjective state of negative feelings about having a lower level of social contact than desired" (AIHW 2021 n.p.). AIHW (2021) notes that loneliness has been linked to premature death, poor physical and mental health and to general dissatisfaction with life. Around one in three Australians commonly report experiencing loneliness at some time, with higher proportions during COVID shut-downs.

Frieling et al. (2018) focus on socialising, social support and sense of belonging as the core elements of social connectedness and suggest that the research base indicates that young adults and older people, people with low socio-economic status, people from dysfunctional family backgrounds, single parents, people living with poor health or a disability, and people living alone are likely to be at most risk in terms of lower social connectedness outcomes. These are similar groups to those who are typically listed as most likely to experience transport disadvantage, so seeking a connection between mobility, social connectedness and mental health is potentially important in terms of identifying potential societal benefits from improved mobility opportunities.

The AIHW conclusion on social isolation and loneliness is that even though they are now well-recognised public health concerns, *there is little research into what works to resolve them* (AIHW 2021 n.p.). This finding is repeated in the literature we scanned on social connectedness and aspects of mental health. Authors such as Frieling et al. (2018) recognise that *opportunities to connect* are important influencers on social connectedness, mentioning access to transportation and the built environment as two specific factors that are relevant here, but we have been unable to identify any quantitative analysis of links between mobility, social connectedness and mental health. This remains an area requiring further research.

7.3 Conclusion

Poor mental health is a large and growing problem in Victoria and elsewhere. It is likely that the ability to be mobile would assist in reducing the associated high personal and societal cost through direct access to support, services and treatment. The ability to be mobile would also be likely to aid the restoration of health through enabling a reduction in factors that lead to, or exacerbate, a mental health condition, through facilitating the important role of social interaction or social connectedness to the achievement of health and wellbeing. This link between transport and mental health and wellbeing is a greatly under-researched area that is likely to show high value if the connections are measured. Research on connections between mobility and social capital/social connectedness is a good starting point.

8. Crime

8.1 Crime costs

The US Government Accounting Office has produced a useful overview of approaches to measuring the costs of crime and challenges associated therewith (USGAO 2017). Four approaches are identified:

1. measuring crime's effects on markets – essentially a hedonic pricing approach, which looks for variations in property prices associated with changes in crime levels;
2. using jury awards to estimate victimisation costs;
3. surveying the public's willingness-to-pay to reduce crime; and
4. calculating categories of costs separately to develop a total cost – a bottom-up approach that seeks to trace through costs associated with particular crimes. This has been the way that crime costing has typically been approached in Australia, as discussed below.

USGAO (2017) also sets out a neat framework within which to categorise the costs of crime, which has much in common with Figure 4.1 in the current report but adds a useful time dimension. Table 8.1 summarises the elements of the USGAO framework, with examples of relevant costs. The USGAO report underlines the difficulty of costing crime, due to factors such as considerable under-reporting of many crimes and challenges in cost estimation, particular in relation to intangible costs (which are more about subjective wellbeing), which they expect to be larger than the more readily quantified tangible costs.

Table 8.1 Categorisation of crime costs

Cost type	Costs in anticipation of crime	Costs as a direct consequence of crime	Costs in response to crime
Tangible	Cost of alarm systems; government crime prevention programs.	Lost wages and productivity; cost to repair and recover.	Criminal justice system costs.
Intangible	Fear of crime; avoidance behaviour.	Pain, suffering and loss of quality of life from victimisation.	Psychological cost to offender's family and the community.

Source: Based on USGAO (2017), Figure 1.

Smith et al. (2014) estimated how much crime costs the Australian economy, their estimate for 2011 being $47.5 billion or 3.4% of national GDP. This estimate was based on a calculation of the number of crimes that come to the attention of the authorities and, drawing on crime victimisation survey data, scaling this up to make an estimate for crimes that are not officially recorded. This is the same approach as is used, for example, in the US. As USGAO (2017) notes, crime data is notoriously under-reported, so the resulting estimates are likely to be highly conservative. Smith et al. (2014) note that their costing has many exclusions, such as:

> *"… the social costs of fear of crime, costs of supporting offenders and their families, local government crime prevention activity, community defensive action, 'second generation' costs of offending (including the costs of victims of crime committing crimes in the future and the costs to the families of offenders through disruption, guilt and dysfunction) and damage to the reputation of victims and offenders (in the case of a financial crime …) and costs associated with disinvestment in high-crime areas, which can be substantial. The nation-wide lost productivity of those individuals committing crimes has not been costed and included in estimates due to lack of available data."*

(Smith et al. 2014, p. 12)

By way of example, in Australia it is estimated that less than 1% of actual arson events result in a criminal conviction, yet arson is viewed as one of the most costly crimes to the community (Stanley et al. 2020). These omissions suggest that the resulting cost estimates will be low, and most probably very low, estimates of the total costs associated with crime, as reinforced in Section 8.2 where some evidence on the wellbeing costs of violent crime is presented.

Smith et al. (2014) include dollar cost estimates for a range of crime events and the associated total cost of each specific crime type, taking frequency into account (Table 8.2). The estimate includes actual loss, some intangible losses, loss of output caused through the criminal conduct and other related costs, such as medical expenses, where relevant. To these costs they add the costs of preventing and responding to crime in the community, in line with the broad USGAO (2017) costing framework illustrated in Table 8.1, which brings in household costs of risk minimisation and the costs of maintaining criminal justice system agencies (police, prosecution, courts and correctional agencies), including part of the costs of the Australian and state and territory agencies that have crime-related functions. Deductions are

made for the value of property recovered in the case of property crime plus funds recovered from criminals under federal, state and territory proceeds of crime legislation. Table 8.2 shows the costs of individual crimes estimated by Smith et al. (2014), together with their unallocated costs (of administering the criminal justice system, household precautions, etc.) and with deductions for recoveries.

The identified costs by type of crime total $23 billion, as shown in the top half of Table 8.2, and the unallocated costs are a similar amount, at $24b (lower part of the table). Table 8.2 also shows the implicit average cost per crime type if all the unallocated costs were allocated across the crime types shown, in proportion to their direct costs. Homicide (direct cost $2.7m; scaled up total cost $5.6m) has the highest cost per crime incident, with arson second highest ($51K and $104K respectively). A number of theft type crimes have average costs per incident ranging up to an estimated $6420 direct costs and $13,250 total cost (including unallocated costs), the highest being for vehicle theft.

All these unit costs of crime events can be expected to have increased since the 2011 costing period. For example, the Productivity Commission's Report on Government Services 2021 (Productivity Commission 2021) suggests that justice services cost $19.7b in 2019/20 (Police $12.7b, corrective services $5.1b and courts $1.9b). The most comparable figure in Table 8.2 is $16.3b for criminal justice costs, suggesting an increase of around 21% over the intervening period (over ~ 7 years, which seems to be of the expected order of increase). McLachlan et al. (2013) argue that not all these costs are avoidable with respect to disadvantage but suggest that they do provide an upper bound cost estimate. On the other hand, inclusion of omitted costs from the Smith et al. (2014) research will lift the scale of cost estimate.

Costing of the potential crime externality benefits from reduced social exclusion can proceed by estimating reductions in the incidence of particular crimes and applying unit costs for each such event. Alternatively, or perhaps complementary to the event-based approach, estimation could focus on identifying at-risk people and their associated risk trajectories, with and without the intervention that is intended to lower their risk trajectory: in the current case, improved accessibility opportunities through greater public transport (bus) service availabilities.

Table 8.2 The costs of crime in Australia – 2011

Crime type	Recorded victims (n)	Estimated number of crime incidents (n)	Estimated cost ($m)	Average cost per incident ($)	Average cost per incident scaled up by other costs ($)
Homicide	463	463	1250	2699784	5577440
Attempted murder	185	185	)		
Assault	169903	1172333	) 3021	2577	5323
Sexual assault	17592	198109	775	3912	8082
Robbery	13617	72765	267	3669	7580
Burglary		753280	1645	2184	4511
Theft of vehicles	55382	65600	421	6418	13258
Thefts from vehicles	168666	379200	691	1822	3765
Shop theft	80625	1298063	124	96	197
Other theft	269000	807117	605	750	1549
Criminal damage	249220	1470398	2275	1547	3196
Arson	14975	44925	2269	50506	104340
Fraud	97611	1047185	6052	5779	11939
Drug abuse			3161		
Sub-total crimes			**22995**	**n.a.**	**n.a.**
Criminal justice			16256		
Victim assistance			1877		
Security industry			3400		
Insurance admin.			670		
Household precautions			2360		
Sub-total other			**24563**		
Total crime and other			**47555**		
Less assets confiscated			63.6		
Total			**47505**		

Source: Smith et al. (2014), Tables 2 and 3 and current authors' estimate with spreading of unallocated costs.

Allard et al. (2013, a, b) estimate the costs of offender trajectories in Queensland. They identify five offender trajectories: two chronic, one moderate and two low trajectories. They found that the average cost of each adolescent onset (chronic) offender was $186,366 and the average cost of each early onset (chronic) offender was $269,799. The average cost of each adolescent peaking (low) offender was $8559 and each adult onset (low) offender cost $10,470. In other words, on average, each chronic offender cost over 20 times more than offenders in the two low offending groups. By implication, policy initiatives that removed one chronic offender from offending would deliver cost savings of around $200,000 (2012 prices), or around $10,000 for low offender types, with the savings implicitly spread across the crime types shown in Table 8.2, as appropriate to different offender categories.

8.2 Causes of crime

The causes of crime are far from established in the literature, in part due to the little research that has been undertaken on this issue. Two broad causes are accepted, being the functioning of the family and poverty, although the complex associations between these issues are disputed (Jahanshahi et al. 2021). In relation to family, children need to make choices, engage in activities that solve problems and enable self-regulation, as crime prevention approaches (Heckman et al. 2013). Stuart and Taylor (2021), in their examination of crime reports from 1970 to 2009 across US cities, found that social connectedness leads to a sizeable reduction in crime rates across seven types of crime, including personal and property crimes.

Community connections are also said to be important, where residents can work together to solve problems and build trust (Homel et al. 2015). Heckman et al. (2013) talk of mutually supportive practices between schools, parents and other organisations, that have crime reduction outcomes. Structural deprivation at the neighbourhood level is said to be a strong predictor of offending even where there are high protective factors in the family (Jahanshahi et al. 2021). However, there is little evidence of research on infrastructure and crime, and *governments struggle to find the policy needed to reduce the structural inequalities* (Jahanshahi et al. 2021, p. 4). While Wo (2019) has undertaken a small amount of work on the physical structural qualities of a neighbourhood and land-use planning, the authors of this report are yet to find work on the role of transport or mobility in crime prevention. As with mental health, we expect that links between mobility and social capital or social connectedness to crime is likely to be a fruitful pathway for examination, as suggested in the couple of studies on social connections.

Some possible areas of application are worth noting. Poor land use transport planning associated with rapid population growth might be expected to lead to concentrations of problematic and antisocial behaviours. For example, youth unemployment sits between 15% and 20% in many of the outer fringe suburbs of Melbourne. This measure of youth unemployment does not include under-employment, nor include those disengaged from education and searching for work. In February 2017, the under-employment rate for youth aged 15 to 24 years of age sat at about 18% (Vandenbroek 2017). Such high levels of unemployment and underemployment are a risk in terms of problematic behaviours. We illustrate this with the example of wildfire arson.

A major concern in Victoria is the extensive impact of the crime of wildfire arson, where the cost encompasses many areas. Wildfire may cause loss of life and physical injury as well as health impacts from smoke. The loss of housing and other buildings is particularly problematical where insurance is insufficient to rebuild or where there is an absence of insurance. Wildfire commonly leads to agricultural and forest losses, impacting on stock and biodiversity (Stanley et al. 2020). Disturbed behaviour is more common after a severe fire, where substance abuse, family violence, self-harm, and suicides can rise as much as 8% (Doherty and Clayton 2011). Both children and adults may suffer post-traumatic stress and lingering behavioural issues associated with fear or anxiety.

Deloitte Access Economics (2016) examined the cost of the 2009 Black Saturday wildfires in Victoria, where about 400 fires occurred between the 5th and 9th February 2009. They estimated the social cost as $3.9 billion but noted that it is likely to be double this value. This figure includes death, physical injury and disability, mental health, alcohol misuse, ill-health including chronic disease, family violence and relationship breakdown. They also included associated crimes (apart from looting directly after the fire), loss of pets, social dislocation and loss of energy and communication networks, loss of heritage and culture. The societal costs associated with fire-planning and suppression are on top of their estimate.

It is thought that up to half of the wildfires in Australia are deliberately lit (Bryant 2008). The largest group of people who commit this crime are youth, predominately male, about 14 to 20 years of age, who also engage in other criminal behaviours such as theft and vandalism (Dolan and Stanley 2010). Older males who engage in fire lighting also have a history of social and educational disadvantage (Doley et al. 2016). Most wildfire crime occurs on the edge of the cities or rural towns, areas that lack infrastructure, leaving youth with lower levels of social inclusion and opportunities in life, thus vulnerable to committing crime (see for example, Baumeister et al. 2005, Grubb and Nobles 2016). Without transport it is hard to reach education and jobs, make social connections and engage with the local community, resulting in a loss of confidence and self-esteem. The absence of public transport to enable

youth to undertake social connections and activities, further isolates those who move to fringe suburbs, potentially increasing risks of wildfire arson (Stanley 2020).

Youth disadvantage is also present outside Melbourne, in regional settlements, where wildfire ignitions are also higher where urban meets rural areas, when compared with more isolated rural areas (Llausàs et al. 2016). A study of rural transport found that youth in South-Western Victoria experience the highest levels of transport disadvantage and wellbeing levels are lower than those found in urban Melbourne as a whole (Stanley and Banks 2012, unpublished findings from ARC study). Rural youth were often not able to take advantage of education initiatives designed to keep youth at school, such as the VET and VCAL (the Victorian Certificate of Applied Learning schemes), nor take up job opportunities on farms, due to an absence of transport to access these opportunities. Youth who have never experienced being in the workforce full-time and are unable to get work risk longer-term disadvantage through loss of motivation and a reduction in 'employability'.

Children and youth are at risk of on-going disadvantage where they do not have access to lift giving by family or friends and there is an absence of public transport to enable access to friends, sport and other desired activities (social capital enhancing) and schooling. Such entrenched disadvantage appears to be linked to wildfire ignition and often in a group situation. Land use and infrastructure planning, together with transport availability along the lines of the 20-minute neighbourhood, is likely to see a reduction in such crimes, but these links are yet to be fully researched. With very high levels of youth unemployment in the outer suburbs of Melbourne and many rural settlements, and the link between unemployment and crime, and the lack of local public transport, the associations are visibly there, even although not yet sufficiently researched.

8.3 Crime economics and subjective wellbeing

The cost discussion in Section 8.1 does not provide insight into the impacts of crime on subjective wellbeing and the scale of cost or loss associated therewith. This section sets out some evidence that is relevant to the Australian setting, showing how much larger the subjective wellbeing costs associated with crime are than the costs set out in Section 8.1.

Kuroki (2013) explored the costs of burglary (taking something from the home) and robbery (taking something from the person by force) in Japan. Using a 5 point happiness scale, Kuroki found that burglary victims' happiness is an average of 0.14 points lower than that of people who have not been burgled. If this was converted to a 10 point scale, such as is used for life satisfaction, the effect size on happiness would be 0.28, which is (coincidentally) similar in scale to that found by Mahuteau and Zhu (2016) in their Australian work.[11] This impact of burglary on happiness is argued by Kuroki (2013) to be equivalent to losing $US35,000-$52,500 in income (prices of about 2005). Robbery was not found to have a significant effect on happiness. The negative wellbeing effect of being burgled was found to be less than that from losing a job (where the relevant coefficient was 0.38 on the 5-point happiness scale, much larger than the 0.14 for burglary). The impact of burglary on happiness is found to be higher at lower household income levels (for reasons such as the rich being better able to protect themselves against this crime).

Mahuteau and Zhu (2016) estimate the effect of physical violence and property crimes on subjective well-being in Australia, noting that Australia had one of the highest rates of victimisation for assaults or threats and for burglary in the OECD. They found that physical violence and property crimes both reduced reported well-being to a large extent, with physical violence exerting a larger average effect than property crimes. They concluded that:

> *"… physical violence and property crimes are associated with a decline of respectively 0.30 and 0.03 standard deviation of the SF-36 mental well-being measure."*

(Mahuteau and Zhu 2016, p. 1449)

They find that the mean impact of physical violence on wellbeing is larger than that for loss of employment, which gives a hint as to the monetary scale of impact.

The SF 36 mental wellbeing measure, which was the main outcome indicator used by Mahuteau and Zhu (2016), is different to the wellbeing measures used by Stanley et al. (2021a) to impute monetary values to changes in wellbeing. Fortunately, however, Mahuteau and Zhu (2016) also present findings for the effects of physical violence and property crimes on subjective wellbeing (Life satisfaction), which can be aligned with the Stanley et al. (2021a) values. They find that victims of physical violence report mean levels of subjective wellbeing (SWB) some 1.05 units lower than those who do not experience such crime (6.78 compared to 7.83 mean SWB scores respectively). Victims of property crime report mean SWB scores 0.35 units lower than those not experiencing this crime (7.48 compared to 7.83). Once control variables are introduced in modelling of SWB (e.g., age, married, years of schooling, household income, family size, etc.), the effect size reduces to 0.396 for (a unit increase in) physical crime and 0.094 for property crime. These scales of impact remain significant. Interestingly, their analysis finds that the SWB impacts are greater at lower levels of SWB than at

[11] Happiness and life satisfaction questions differ, so cannot be argued to be measuring the same thing, albeit that they are similar.

higher levels, introducing an equity perspective to how the results of the analysis might be used.

Stanley et al. (2021a) estimate that a unit change in subjective wellbeing (measured by the Personal Wellbeing Index) is worth $124/day in 2008 prices. Applying this value to the Mahuteau and Zhu (2016) effect sizes for physical crime (0.396) and property crime (0.094) suggests a subjective wellbeing cost of $49/day and $11.65/day respectively. This converts to an annual subjective wellbeing cost of $17920 for physical crime and $4250 for property crime (assuming 365 days a year). Conservatively updating these values to 2019 prices (by CPI increase from 2008) increases the wellbeing cost of physical crime to $22,450 and $5325 for property crime.

Johnson et al. (2017) analyse the amounts of compensation that would need to be paid to victims of violent crime to restore their wellbeing to preceding levels. Their analysis is based largely on data from Australian HILDA surveys between 2002 and 2012. They found that being the victim of violent crime over the last 12 months has a large negative effect on life satisfaction, averaging 0.398 for females and 0.300 for males, which was much larger than for property crime (not analysed in their paper). The mean and median life satisfaction scores for both females and males were close to 8 in their data set, so a reduction of 0.3 to 0.4 is substantial. It is noteworthy that this scale of impact is of the same order as estimated by Mahuteau and Zhu (2016), once control variables are included in the analysis, also using Australian HILDA data, albeit for a slightly shorter number of years. This provides some confidence in using the relevant estimates of associated wellbeing costs. An interesting finding from the Johnson et al. (2017) research was that average effects conceal considerable heterogeneity across the SWB distribution: physical violence has twice the negative impact at the bottom end of the SWB range, compared to the average, while the effect decreases as SWB increases and is not significant at the top end. Property crimes have a similar pattern over the SWB range but with smaller magnitude impact on SWB.

Johnson et al. (2017) calculate that a mean sum of $87,900 would be needed to compensate for the reduction in life satisfaction associated with violent crime victimisation, with $79300 for males and $101,800 for females. The paper by Johnson et al. (2017) does not make it clear what price levels are used in their analysis but we assume that it is across the period to which their data applies, which would suggest it is probably representative of perhaps 2007. Their value is similar to the value estimated in Section 6 of the current report for the increase in subjective wellbeing for someone moving from being unemployed and looking for a FT job to being employed FT. However, that figure was in 2019 prices, whereas the Johnson et al. (2017) figure seems to be in prices from about 2007. That suggests that the subjective wellbeing cost of violent crime victimisation is larger than the value of loss/gain of FT employment. Johnson et al. (2017) derive their estimates by comparison with the wellbeing (life satisfaction) impacts of an income shock, rather than by comparison with the life satisfaction differences associated with changes in permanent income. Given the sporadic nature of violent crime (fewer than 2% of the respondents to the HILDA survey were victims of such crime), the comparison with the life satisfaction impacts of another sporadic change (an income shock), rather than permanent income, seems an appropriate valuation approach.

The monetary values from the Johnson et al. (2017) study are much larger than the cost estimates for violent crimes that were set out in Table 8.2, except for homicide, suggesting that costing approaches that rely mainly on costing actual expenditures incurred by governments or citizens substantially undervalue the prospective societal costs associated with crime, particularly violent crime, in monetary terms. Applying the values for a change in subjective wellbeing from Stanley et al. (2021a) to effect sizes estimated by Mahuteau and Zhu (2016), which are similar to the effect sizes found by Johnson et al. (2017), produces a much lower subjective wellbeing cost than that estimated by Johnson et al. (2017) but still considerably larger than the comparable cost estimates shown in Table 8.2.

8.4 Conclusions on crime

There is a growing evidence base on the substantial cost of crime, both in terms of property type measures and also measures linked to wellbeing. However, as with mental health, we have found no quantitative evidence that links crime outcomes with mobility opportunities. There is an a priori expectation for such a connection, because (for example) improved mobility opportunities can be expected to support increased social inclusion (as we show in Section 9) and to support stronger social capital. Yet the pathway from mobility to inclusion and then on to crime remains to be explored.

9. Community/neighbourhood level effects on risk of social exclusion and implications for the value of mobility[12]

9.1 Approach

This section of the report considers whether there might be external benefits from mobility improvements that accrue at community or neighbourhood level, in addition to those that arise at the level of an individual, the latter having been the focus of the report thus far. Neighbourhood quality impacts on life quality, child development and personal opportunities (e.g., Shields and Wooden 2003; Christian et al. 2017). The absence of a place-based impact may pose some questions about the robustness of the monetary values estimated in Stanley et al. (2021a) and may mean that insights into ways of reducing risk of exclusion are missed. It is arguable that the modelling process should have included a measure or measures of the neighbourhood within which respondents live, particularly in relation to issues of spatial disadvantage, given the focus on social exclusion for monetisation. The current section of this report deals with this refinement. The substantial contribution of Professor David Hensher to this section of the report is gratefully acknowledged.

Discussion of neighbourhood and neighbourhood character in a planning context commonly focusses on the physical environment of an area, such as its pattern of development, built form, architectural styles, street trees, waterways and such like. The interest is sometimes in how such factors contribute to land values, with hedonic pricing sometimes used to impute monetary values to various influencing factors (e.g., Hui et al. 2007; Chung 2015; Fleming et al. 2018). Hedonic pricing has been used to identify potential benefits from new transport projects (Gibbons and Machin 2008; Redfearn 2009; Dube et al. 2011, 2013; Mulley 2014).

The following discussion is interested in more than the built environment. The interest extends to the quality of a neighbourhood in terms of its people interactions, with a particular focus on how neighbourhood disadvantage might impact risk of social exclusion. Social capital and sense of community, which are often included within discussion of neighbourhood characteristics, are already part of the modelling process used by Stanley et al. (2021a). The focus here is on broader place-based socio-economic conditions that might promote or hinder inclusion.

The primary intent of what follows is to explore the association between neighbourhood disadvantage and risk of social exclusion. Having identified an association, we then explore what impact the inclusion of this association has on the monetised values of trip making and of other influencing factors, as they relate to the personal risk of social exclusion, as estimated in Stanley et al. (2021a). In particular, might those monetised values be substantially changed if neighbourhood disadvantage is included as a potential contributor to risk of social exclusion?

Section 9.2 reviews some of the literature on neighbourhood effects, focussing on how neighbourhoods function to increase or reduce exclusion and on challenges in identifying these effects. Section 9.3 describes the data collection process, particularly the choice of an indicator of disadvantage, and discusses the modelling work on risk of social exclusion. Section 9.4 uses the modelling work from Section 9.3 to impute monetary values to changes in trip making and in other significant variables from the modelling. It finds that the monetary value of additional trip-making remains robust in the face of an additional explanatory variable, concerning neighbourhood disadvantage. That section introduces an important new perspective, showing how the value of an additional trip changes with the level of social exclusion risk faced by an individual. Section 9.5 asks the question “What it is that we are actually valuing when we value trips in a social exclusion context?” Section 9.6 sets out the section’s conclusions.

9.2 Literature review

The study of neighbourhood effects gained much impetus in the UK under the new Labour Government around the turn of the century, with programs such as *New Deal for Communities* and *National Strategy for Urban Renewal* (Lupton 2003). This interest in the neighbourhood led to a range of social programs, which were replicated in the US and Australia, such as *Neighbourhood Renewal* and *Communities for Children* (Hydon et al. 2005; Stanley et al. 2006).

[12] A version of this section of the report has been sent to Transportation Research Part A for potential publication.

Atkinson and Kintrea (2001) suggest that neighbourhood policy implies a belief that where people live effects their chances to participate in an inclusive society, it also being argued that neighbourhoods bring a distinctive set of resources to facilitate social inclusion (Murie and Musterd 2004). However, it has proved difficult to disentangle those resources derived from neighbourhood and those due to individual characteristics (Chavis and Wandersman 1990). Indeed, neighbourhood, *per se*, is rarely a research topic, the focus more commonly being on how neighbourhood impacts a particular subject of interest, such as child development or mental illness. Thus, research on neighbourhood is widely spread through many disciplines, often lacking common definitions and an integrating theory.

Interest in the importance of neighbourhood is growing again, both as a source to promote capabilities and a force for building responses to societal threats, such as climate change and biodiversity loss. A number of matters discussed in the literature on neighbourhood effects are relevant to the current research: what is a neighbourhood; what is a neighbourhood effect and what outcome variables are likely to be influenced by neighbourhood effects; what data is needed to inform research on such matters; and, what analytical methods are most suited to such research? The following literature review is structured around these questions.

What is a neighbourhood?

Lupton (2003) argues that the concept of neighbourhood is not a given and that different ways of looking at neighbourhood might be needed to assess different issues (e.g., different spatial scales). Shields and Wooden (2003) also note the challenge of defining a 'neighbourhood', pointing out that it is not the same as 'community'. Neighbourhoods are often defined in terms of people living/engaging in activities in close proximity, whereas communities may (for example) extend beyond such neighbourhoods or parts thereof (e.g., communities of interest). Neighbourhoods may also be described in terms of other characteristics, Kress et al. (2020) (for example) using environmental character, built form, geography (walking distance to public transport and distance to work) plus institutional characteristics (walk distances to a range of services) as their indicators of neighbourhood.

Knies et al. (2020) also point to recognised problems in defining neighbourhoods and how different boundaries may be needed to explore different issues, recognising that different causal mechanisms may operate at different neighbourhood scales. However, their analysis of UK data finds no evidence of variation in the size of the association between neighbourhood deprivation and individual wellbeing across a range of neighbourhood scales. Their main policy conclusion is to target individual disadvantage but, given the tendency for spatial concentration of disadvantage, they also recognise that spatial targeting can still be an effective way of reaching large numbers of people in need.

What is a neighbourhood effect and what outcome variables are likely to be influenced by neighbourhood effects?

Outcome variables in research on neighbourhood effects span a range of matters, such as mental and physical health, educational achievement, poverty, house prices, life satisfaction/subjective wellbeing, crime, social and occupational mobility and social exclusion (e.g., Shields and Wooden 2003; Gibbons and Machin 2008; Hedman et al. 2015; Kress et al. 2020; Knies et al. 2020). The outcome variable of interest in the current research is (risk of) social exclusion. The literature review thus concentrates mainly on research that has examined linkages between neighbourhood effects and social exclusion and related matters, though some of the methodological literature that is included has different outcome targets.

Shields and Wooden (2003) summarise some of the reasons why a link between neighbourhoods and social exclusion could be expected. They suggest that:

> *"Communities that are strong' are expected to deliver more positive outcomes, which include increased employment opportunities, higher rates of social and civic participation, better educational performance by children, lower rates of crime, and improved physical and mental health."*
>
> (Shields and Wooden 2003, p. 1)

If these associations are found, then strong communities would be expected to have fewer residents with risk of social exclusion, a finding confirmed by aspects of the analysis in Stanley et al. (2011b, 2021a). This quotation also highlights the neighbourhood/community question. Shields and Wooden (2003) focus on life satisfaction (wellbeing) as their outcome measure and conclude that, in terms of neighbourhood effects, this is likely to be influenced by the degree of positive social interaction that occurs at the neighbourhood level.

Van Hamm and Manley (2012) and Jivraj et al. (2019) are critical of the failure of researchers to explain how causal mechanisms work in neighbourhood effects research, both recognising the contribution of Galster (2012) in this regard, who identifies four types of causal pathway between neighbourhood and individual behavioural and health outcomes: social interactive, environmental, geographical and institutional. Chavis and Wandersman (1990) argue that there are three important factors that determine neighbourhood impact: the quality of the physical environment, the social environment, and control and empowerment that leads to collective efficacy or working together. Both lists cover similar issues.

The quality of a neighbourhood's physical environment could relate to the presence of abandoned buildings, litter and crime impacts on feelings of safety on streets (Wandersman and Nation 1998; Baumeister et al. 2005; Grubb and Nobles 2016). This 'quality' of the neighbourhood might then impact social interaction. Neighbourhood structure is also important, as opportunities such as parks, town squares, market and sporting facilities, as well as cafes and bars, all facilitate personal interaction and a sense of commonality and belonging (Lehman 2015; Wood et al. 2017). Attractive streets with shelter and shade provided by trees, seating and tables and planters all encourage people to stop in a public place, foster social capital and build social inclusion (Mehta 2009; Stanley et al. 2017). Neighbourhood characteristics can challenge perception of control over life and disconnectedness with your community, and loss of protective resources.

A neighbourhood can thus provide opportunities to build social capital and may include good public transport accessibility to shops and services, helping to reduce disadvantage (Christian et al. 2017). In a major comparative study, Murie and Musterd (2004) found that, although a neighbourhood may have low job opportunities and poor infrastructure and community facilities, very good transport links, services and strong support networks can improve social inclusion.

Thus, the *resources that the neighbourhood has are partly the product of the characteristics of the population and the characteristics of the population are in turn partly the product of these resources* (Murie and Musterd 2004, p. 1455). Thus, the way we are shaping cities and urban development impacts on personal life chances, impacting on social inclusion and levels of disadvantage (Stanley 2020). Importantly, Lupton (2003) argues that even if research sometimes suggests that neighbourhood effects may be small, there remain good grounds for area-based policy interventions, such as social equity and the efficacy of tackling concentrations of disadvantaged individuals with initiatives that are geared at those individuals.

What data is needed to research neighbourhood effects on social exclusion?

Lupton (2003) suggests that lack of suitable neighbourhood-level data stands as a major limitation on quantitative research on neighbourhood effects, research often being driven by data availability rather than what by data is actually required to analyse the issue at hand. Gibbons and Machin (2008) express similar concerns in relation to their UK research.

Data on social connections is seen as important by many researchers (e.g., Shields and Wooden 2003; van Hamm and Manley 2012; Kress et al. 2020) but measures of such connection vary and are commonly narrowly based, particularly when they draw on broad (national) panel surveys. For example, Kress et al. (2020) use Likert scale responses to just three questions, covering how people see the importance of being socially and politically active as an aspect of participation in the neighbourhood's life, being worried about crime in the neighbourhood as an aspect of trust and being worried about the hostility to foreigners as an aspect of tolerance or respect at neighbourhood level. Responses were converted into a continuous variable, a questionable practice, whereas ordinal ranking may have been more appropriate for such data.

What analytical methods are most suited to such research?

Bergström and van Hamm (2010) and van Hamm and Manley (2012) argue that, although there has been a growing research base on neighbourhood effects, we are no closer to knowing how important they are, for reasons such as lack of understanding of causal pathways, as noted above, and the confounding influence of residential sorting. This sorting occurs when the selection mechanism into neighbourhoods is not independent from the outcome that is being studied. They note the lack of studies of neighbourhood effects that have sought to control for sorting. Van Hamm and Manley (2012) argue for use of longitudinal data to help understand causal pathways, with Modai-Snir and Plaut (2019) providing a recent example.

Taking a longitudinal approach, Kress et al. (2020) found that social cohesion mediated positively the effect of environment and built form characteristics on mental and physical health, with the mediating role increasing over time for physical health. Hedman et al. (2015) examine the effect of neighbourhood poverty over time in Stockholm on personal income in later life, using a longitudinal approach. Looking at home leavers, they find independent and non-trivial effects of parental neighbourhood poverty (low income) and cumulative exposure to neighbourhoods with poverty concentrations on income in later life.

Knies, Melo and Zhang (2020) examine how residential sorting might affect the relationship between neighbourhood characteristics and individual wellbeing. They find that the effect of neighbourhood deprivation on life satisfaction and hourly earnings is sizeable and statistically significant but that there is a strong role for residential sorting, in that residents move to a preferable neighbourhood when this is affordable, concluding that the main cause of inequality in individual wellbeing outcomes is due to individual disadvantage rather than where people live. However, while this may explain why disadvantage is geographically clustered, the issue is independent of how the neighbourhood impacts the social exclusion of some residents.

This literature overview suggests that, in terms of the purposes of the current study, personal and neighbourhood characteristics should both be included in modelling to understand risk of social exclusion, and that the concept of neighbourhood is difficulty to tie down, having a number of different elements and scales. It also suggests there will be tension between the personal and neighbourhood level data needed to understand associations with exclusion risk, which needs detailed survey-based material, and data availability from longitudinal research that is suited to examine causality, where detail is inevitably much reduced. The current study uses detailed survey-based material, not longitudinal data, for reasons explained below.

9.3 Data and modelling

This research builds on Stanley et al. (2021a), using the same data set to, among other things, verify the robustness, or otherwise, of monetised values of trip making developed in that research, once neighbourhood disadvantage is included amongst the factors used to explain risk of social exclusion. As Stanley et al. (2021a) explain (and as was discussed in Section 6 above), that rich data set collected information on factors such as social exclusion risk, social capital, connectedness to community, subjective wellbeing, psychological well-being, personality, transport problems, demographics and household composition, through personal interviews. However, the data set did not include measures of neighbourhood condition, other than respondent perceptions of various aspects of neighbourhood, which included matters such as sense of community, various aspects of social capital, perceptions of safety and questions about home location choice. No spatial or area-based measures of neighbourhood were included in the analysis.

Reflecting on the findings from the literature review, the data source used for the current study is rich on issues such as social connectedness and related matters (e.g., bridging and bonding social capital, sense of community, personal wellbeing), including social exclusion, much more than the comparable data sets used by most studies of this topic, but it is cross-sectional data, not longitudinal, such that causal pathways are potentially more problematic. That is not a major concern, since the main purpose of the research is not to explore neighbourhood effects in depth from a causal perspective so much as to see whether including a measure of neighbourhood causes major changes in the contribution of other explanatory variables to explaining risk of social exclusion, since that could pose questions about the robustness of monetisation. It is acknowledged, however, that if neighbourhood effects operate with a lag, the use of cross-sectional (point of time) data will not fully pick up the accumulated impacts.

Since the focus is on trying to better understand risk of social exclusion, a spatial measure of *neighbourhood disadvantage* was added to the personal measures used by Stanley et al. (2021a). A higher level of neighbourhood disadvantage was expected to increase risk of social exclusion. The person-level data set available for the research included details of a respondent's postcode, which was the only data available on which to base a spatial measure of 'neighbourhood' disadvantage. Average population number in a Melbourne postcode area at the time of the survey was around 20,000. Given Melbourne's gross population density at the time, this suggests an average postcode area size of about 35 square kilometres, which would put most people aged 15 or over (survey respondents) within about 3-4 kilometres radial distance from the geographic centre of their postcode. This should cover most activity and services needs for residents, which is one way of describing a neighbourhood. Distances would be greater in outer areas, where densities are lower, but less in inner areas. Many Melburnians would think of their neighbourhood in terms of their postcode but others might align their neighbourhood with (for example) a suburb, which may be smaller than a postcode, or an even smaller locale. However, place of residence was only identified with postcode in the survey that provides data for this research, so postcode level information on neighbourhood is used herein, of necessity, mirroring one of the data challenges noted in the literature review.

For a measure of postcode (neighbourhood) disadvantage, the study used the Australian Bureau of Statistics (ABS) Index of Relative Socio-economic Disadvantage (IRSD), one of a range of measures the ABS calls Socio Economic Indexes for Areas (SEIFA) (ABS 2013). The IRSD summarises variables that indicate relative disadvantage, ranking areas on a continuum from most disadvantaged to least disadvantaged, with the weight contribution of each socioeconomic dimension (not shown below) derived from Principal Components Analysis (ABS 2018). Census variables included in the 2011 IRSD (the closest census to the survey date) were:

- % people with stated annual household equivalised income between $1 and $20,799 (approximately the 1st and 2nd deciles);
- % families with children under 15 years of age who live with jobless parents;
- occupied private dwellings with no internet connection;
- % employed people classified as 'labourers';
- % people aged 15 years and over whose highest level of education is Year 11 or lower (includes Certificate I and II);
- % people (in the labour force) unemployed;
- % occupied private dwellings paying rent less than $166 per week (excluding $0 per week);

- % one parent families with dependent offspring only;
- % people aged under 70 who have a long–term health condition or disability and need assistance with core activities;
- % occupied private dwellings with no cars;
- % people aged 15 and over who are separated or divorced;
- % occupied private dwellings requiring one or more extra bedrooms (based on Canadian National Occupancy Standard);
- % employed people classified as Machinery Operators and Drivers;
- % employed people classified as Low Skill Community and Personal Service Workers;
- % people aged 15 years and over who have no educational attainment; and
- % people who do not speak English well.

These Census indicators relate to various characteristics of individuals, aggregated on a spatial basis and it is this aggregated impact on a spatial basis (postcode) that is relevant to this paper. As noted in the literature review, however, neighbourhood impacts relate to the interface between people, structures and service availability. Comprehensive spatial measures of neighbourhood structure and services are not readily available, but these are likely to be highly correlated with spatial measures of disadvantage/advantage, partly as a reflection of residential sorting. For example, poorer areas will often lack the revenue base to provide high levels of services to residents. Given this high expected correlation with concentrations of disadvantage, as reflected in the IRSD components, use of the IRSD measure should be a reasonable proxy for 'neighbourhood' more broadly conceived, given the study's interest in social exclusion.

The IRSD measure provides a comprehensive assessment of relative disadvantage but carries the associated consequence that it does not assist greatly with targeting of measures to reduce disadvantage. IRSD decile rankings for each postcode were used, the lowest decile being the most disadvantaged and the highest the least disadvantaged. These were then grouped into three categories for modelling purposes, recognising that the variables are not continuous: deciles 1 to 3 (called SEIFA13 herein = most disadvantaged postcodes, with 214 survey respondents coming from such postcode areas); deciles 4 to 6 (called SEIFA46 = medium disadvantaged; 244 respondents); and deciles 7 to 10 (SEIFA710 = least disadvantaged; 324 respondents).

Risk of social exclusion is the dependent variable used in this analysis. As explained by Stanley et al. (2011a), it is built on work by Burchardt et al. (2002), with a person's risk of social exclusion defined by five dimensions, with a threshold point that suggests a risk of exclusion noted in brackets, as follows.

- Household income (less than $A500 gross per week, in 2008 prices) (linked to the rate of aged pension for a couple in Australia at the time of the original research interviews).
- Employment status (not employed, retired, in education or training, undertaking care duties or doing voluntary work).
- Social support (not able to get needed help from close or extended family, friends or neighbours).
- Participation (did not attend a library, sport [participant or spectator] hobby or arts event in the past month.
- Political activity (not contributing to, or participating in, a political party, campaign or action group to improve social/environmental conditions, or to a local community committee or group, in the past 12 months.

Extent of social exclusion risk was determined by summing the dimensions where the threshold level applied to the person, each dimension receiving equal weight. Risk of Social Exclusion is thus a categorical variable with up to six possible categories, including zero: zero represents lowest exclusion risk and 5 is highest risk (i.e., all risk indicators apply).

Following Stanley et al. (2021a), in terms of other explanatory variables included in the current study, risk of social exclusion was expected to reduce with increases in Subjective Wellbeing, Bridging Social Capital, Bonding Social Capital, Sense of Community, Trips (trip making being indicative of involvement in activities, suggestive of inclusion), Household Income and if a person was Aged 15-17. It was expected to increase if a respondent was part of a special survey carried out on people thought more likely to be at risk of exclusion.

The Personal Well-being Index (PWI) (Australian Centre on Quality of Life 2017) was used as a measure of subjective wellbeing. PWI contains eight items assessing one's level of satisfaction, with questions for seven theoretically derived quality-of-life domains and an overall question. Responses are on ten-point scales ranging from 'completely dissatisfied' to 'completely satisfied'. Responses across all questions were averaged to derive a respondent's subjective well-being score.

A person's interpersonal network was used as a proxy for social capital. Six-point choices for frequency of contact ranged from 'never' to 'most days' across a range of networks. Bonding social capital networks comprised: members of your close family; members of your extended family; friends/intimates; and neighbours. Bridging social capital networks comprised: work colleagues; and people associated with groups in your community (such as church, sporting, clubs, school, self-help or voluntary groups). For a

person who responds to each category of network, the range of possible scores for bonding social capital under this set of assumptions was from 3 to 24 and, for bridging social capital, from 2 to 12. Both bridging and bonding capital total scores were grouped into high, medium and low ranges, to reflect the data's inherently ordinal nature.

Sense of Community was measured using the Sense of Community Scale (McMillan and Chavis 1986), a widely used measure of psychological sense of community. This is a 12-item measure, with answers measured on seven-point Likert scales, from 'strongly disagree' to 'strongly agree'. Scores were aggregated, in accordance with the structure of the scale (some items added, others subtracted), and then categorised into high, medium and low ranges, as with social capital measures. The SEIFA variable was explained above, while the household income, trips and age variables are self-explanatory.

The sample selection process invited a number of travel survey respondents to opt into an additional comprehensive home-interview survey. People at high risk of social exclusion tend to not complete travel diaries, so a special survey targeted such people at welfare agency offices. This was identified in the modelling by use of a dummy variable, to indicate if the respondent was part of the main survey or the special survey, the latter being very likely to be at relatively high risk of exclusion (by selection). Table 9.1 sets out summary data all on the variables that have been modelled.

Table 9.1 Descriptive statistics for some key variables relating to risks of social exclusion: Metropolitan Melbourne survey respondents (2008)

Variable	Units	Sample mean (standard deviation) (N=768)
Risk of social exclusion	Number of exclusion thresholds met (up to 5)	1.05 (1.08)
Personal Wellbeing Index	Personal Wellbeing Scale (0-10, cont. scale)	7.10 (1.62)
Number of trips on travel day	Trips/day	3.65 (2.62)
Household income per day	$/day in 2008 prices	225.63 (145.27)
Sense of community: Low	Categorical variable derived from composite index	.2370 (.4255)
Sense of community: Medium	Categorical variable derived from composite index	.6393 (.4805)
Bridging Capital: Low	Categorical variable derived from composite index	.3424 (.4748)
Bridging Capital: Medium	Categorical variable derived from composite index	.2891 (.4536)
Bonding Capital: Low	Categorical variable derived from composite index	.3424 (.4748)
Bonding Capital: Medium	Categorical variable derived from composite index	.2891 (.4536)
Age	Years	44.51 (20.34)
Age 15-17	Number in household	1.57 (.50)
Special Sample	1=yes; 0=no.	0.67578 (.46)
SEIFA13	Categorical variable derived from composite index	0.2721 (.4453)
SEIFA46	Categorical variable derived from composite index	0.3138 (.4643)

Given that the dependent variable is an ordered scale, the ordered logit model (Greene and Hensher 2010) is selected for model estimation. Let Y_i^* denote an unobserved (or latent) continuous variable ($-\infty < Y_i^* < +\infty$), defined in utility space, and $\mu_0, \mu_1, \ldots, \mu_{J-1}, \mu_J$ denote the threshold utility points in the distribution of Y_i^*, where $\mu_0 = -\infty$ and $\mu_J = +\infty$. Define Y_i to be an ordinal (observed) variable for social exclusion such that $Y_i = j$ if $\mu_{j-1} \le Y_i^* \le \mu_j$; $j = 1,2,\ldots,J$ response levels. Since Y_i^* is not observed, the mean and variance are unknown. Statistical assumptions must be introduced such that Y_i^* has a mean of zero and a variance of one. To make the model operational, we define a relationship between Y_i^* and Y_i. The ordered choice model is based on a latent regression model given as equation (1) (Greene and Hensher 2010).

$$Y_i^* = \boldsymbol{\beta}'\mathbf{x}_i + \varepsilon_i, \quad \varepsilon_i \sim F(\varepsilon_i \mid \boldsymbol{\theta}), \; E(\varepsilon_i) = 0, \; Var(\varepsilon_i) = 1 \qquad (1)$$

where $\boldsymbol{\theta}$ collects the mean and threshold parameters. The observation mechanism results from a complete censoring of the latent dependent variable as follows:

$$\begin{aligned} Y_i. &= 0 \text{ if } Y_i^* \le \mu_0, \\ &= 1 \text{ if } \mu_0 < Y_i^* \le \mu_1, \\ &= 2 \text{ if } \mu_1 < Y_i^* \le \mu_2, \\ &\ldots \\ &= J \text{ if } Y_i^* > \mu_{J-1}. \end{aligned} \qquad (2)$$

The probabilities which enter the log likelihood function are given by equations (3) and (4).

$$\text{Prob}(Y_i = j) = \text{Prob}(Y_i^* \text{ is in the } j\text{th range}) \quad (3)$$

$$= F(\mu_j - \boldsymbol{\beta}'\mathbf{x}_i) - F(\mu_{j-1} - \boldsymbol{\beta}'\mathbf{x}_i),\ j = 0,1,\ldots,J \quad (4)$$

After extensive analysis where we investigated random threshold parameters and parameters associated with the explanatory variables, including an error components assessment and interactions between various explanatory variables, we found that the simpler model summarised in Table 9.2 obtained the best statistically significant set of parameters, and with exception of the quadratic form for household income, all other variables enter as linear effects, many of which are dummy variables.

The model suggests that low personal levels of Sense of Community, Bridging Capital and Bonding Capital, together with living in an area with a low SEIFA rating, will increase the probability of risk of social exclusion, as will being part of the special survey sample. Conversely, increased household income (squared) and an increased number of daily trips, a reflection of increased engagement in activities, will reduce the probability of exclusion risk. These directions of influence are all as expected.

The way neighbourhood spatial disadvantage, as reflected in the SEIFA groupings, influences risk of social exclusion was explored in some depth. For example, the neighbourhood or spatial context effect may be conditioning the influences that have a direct effect on an individual's probability of being socially excluded or it may alternatively be exerting an additional (additive) influence. To investigate such possibilities we ran a series of models:

1. the individual specific direct influences only, with neighbourhood effects additive;
2. the individual specific direct influences as well as conditioning these influences on neighbourhood effects, as interactions. This assumes that individual specific effects have a role separate from the neighbourhood effect but that there are also additional neighbourhood effects influencing individual specific effects; and
3. the conditioning of individual specific direct influences by neighbourhood effects only, on the assumption that the neighbourhood effect conditions every individual specific direct influence. This assumes that the individual specific effects are all conditioned on neighbourhood effects, rather than standing alone as individual specific effects.

We found that model form (3) does produce significant parameters on most variables except number of trips. Model form (2) has only one statistically significant conditioning effect but results in some not significant individual specific effects. Model (1) has significant individual specific effects and significant stand-alone additive neighbourhood effects, particularly for SEIFA13. We also investigated whether disadvantage, as measured by SEIFA, may be correlated with unobserved effects and found that there was no statistical evidence of heteroscedastic effect through the error variances. We argue that excluding the standalone individual specific direct effects creates a confounding result, since most of the variability being captured in the interaction between the neighbourhood effect and the individual specific effect is attributed to the latter, and that to exclude these direct effects as a separate influence is behaviourally inappropriate. This resulted in us choosing to focus on Model (1), which is shown in Table 9.2.

Table 9.2 Modelling influences on risk of social exclusion

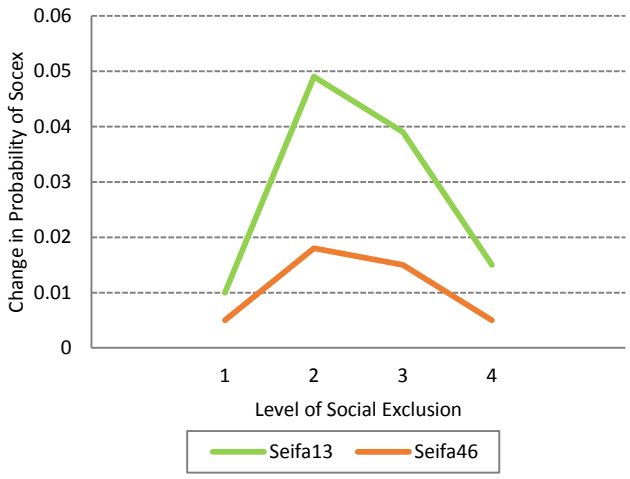
Attribute	Units	Coefficient (z)
Constant		1.3618 (2.37)
Personal Wellbeing Index	0-10	-0.2648 (-5.19)
Sense of Community Low	1,0	1.0499 (3.70)
Sense of Community Medium	1,0	0.4374 (1.84)
Bridging Capital Low	1,0	1.2022 (6.72)
Bridging Capital Medium	1,0	0.6902 (3.73)
Bonding Capital Low	1,0	1.4458 (6.44)
Bonding Capital Medium	1,0	0.4708 (2.92)
Household Income Squared	$/day	-0.0092 (-8.89)
Number of Trips	Number/day	-0.0554 (-1.95)
Number Aged 15-17	Number	0.7210 (4.56)
Sample Type	1,0	-1.0107 (-5.83)
SEIFA 13	1,0	0.4852 (2.63)
SEIFA 46	1.0	0.2456 (1.42)
Threshold parameters for index		
Mu (01)		2.1950 (22.11)
Mu (02)		3.8830 (29.02)
Mu (03)		5.9295 (24.06)
Mu (04)		8.6133 (12.01)
Log Likelihood at convergence		-810.13
McFadden Pseudo-R^2		0.222
AIC/Sample size		2.157

As a result of these various tests, it was concluded that SEIFA is adding additional information associated with explaining the risk of social exclusion of an individual: specifically, it provides recognition that the greater the disadvantage of the overall neighbourhood, the higher the probability of someone being socially excluded, after allowing for individual specific influences. As disadvantage (as reflected in the SEIFA index) increases, the probability of social exclusion risk increases, this effect being significant in the case of the most disadvantaged areas (SEIFA13). Figure 9.1 shows this quite clearly, the probability of someone facing risk of social exclusion increasing across social exclusion (Socex) risk levels 1 to 4, with this increase in risk higher as the level of disadvantage increases (SEIFA 13 is more disadvantaged than SEIFA 46). There were very few respondents with 5 exclusion risks, so levels 4 and 5 essentially collapse to one.

This is an important finding, indicating that risk of social exclusion is influenced beyond the direct impacts at an individual level, being also influenced by the overall level of disadvantage of the spatial setting or context (postcode area in the current study) within which a person lives. Figure 9.1 shows that this increased probability of exclusion is not large, peaking at around 3%, but it is statistically significant in the case of at-risk people who live in the most disadvantaged areas (SEIFA 13).

While recognising the relevance of residential sorting, and that changes in residential mobility patterns affect the magnitude and spatial level of residential sorting (e.g., Modai-Snir and Plaut (2019), even over the short term, we suggest it is not something to be concerned about in a study whose main purpose is to show the person-specific resilience of monetary values in the presence of a specific set of neighbourhood effects at a point in time, the main focus of this paper.

Figure 9.1: Influence of presence and absence of postcode level SEIFA disadvantage on probability of individual risk of social exclusion



9.4 Deriving monetary values

Given that household income squared is statistically significant in the model in Table 9.2, the ratio of other explanatory variables to the household income variable can be used to infer monetary values to changes in levels of those explanatory variables. Table 9.3 sets out the various implicit values, a note to the table showing the formula used to derive a value (using trips as an example). For categorical variables (all except two of the variables in Table 9.3), the implicit values are for moving between adjacent levels of the variable in question. The resulting values are generally higher than found by Stanley et al. (2021a) but not greatly so in the important case of trips, which is the most readily applicable indicator of value or benefit in Table 9.3 for transport policy and project application purposes. The value of a unit change in PWI is a little lower than was found by Stanley et al. (2021a) but the difference is reassuringly small, since this variable is also a potentially useful input for policy and project appraisal.

The model in Table 9.2 implies that the value of an additional trip by someone at risk of mobility-related social exclusion increases, *ceteris paribus*, as household income declines, linked with the specification of household income in the model as household income squared, which was found to be statistically significant compared to linear household income for modelling risk of social exclusion[13]. This is consistent with the finding of Stanley et al. (2011a, b, 2021a). Those seeking to weight the value of the benefits from additional trips as a function of the household income of the trip maker could use the resulting relative trip values, which are shown in the left panel of Figure 9.2.

Table 9.3 Implicit mean values of wellbeing, trips and other key variables ($A 2008)*

Variable and units	Implicit value (sample mean values; $A 2008 prices)
Trips ($/trip)**	20.38
Personal Wellbeing Index ($/day for a unit change)	96.69
Sense of Community – Low to Medium ($/day)	225.37
Sense of Community – Medium to High ($/day)	160.91
Bridging Capital – Low to Medium ($/day)	188.38
Bridging Capital – Medium to High ($/day)	253.93
Bonding Capital – Low to Medium ($/day)	263.80
Bonding Capital – Medium to High ($/day)	173.20
SEIFA 134 to SEIFA 46 ($/day)	88.15
SEIFA 46 to SEIFA 710 ($/day)	90.37

Notes: * This table is based on the sample average across all respondents.
** Calculated as follows, by way of example: MRSTPsHi (-0.05538)/(2*-0.00922*hinc/1000).

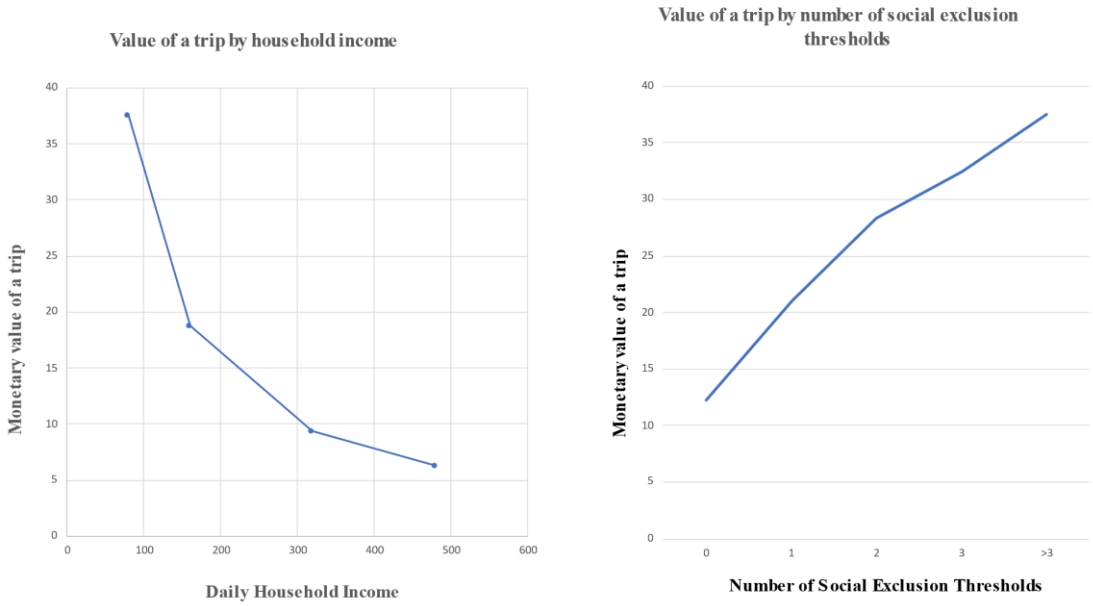
However, social exclusion is a broader concept than poverty (or insufficient income). The indicator of exclusion risk used in the current study has five threshold elements, only one of which relates to income. Three of the five thresholds relate to various forms of participation. If one is interested in reducing exclusion risk, then arguably it is more important to know how the value of a trip may

[13] A separate linear term for household income was problematic and not statistically significant.

change as exclusion risk changes than to know how it changes as household income levels change. The right panel of Figure 9.2 shows how the monetary value of an additional trip changes as the number of exclusion risk factors change. It shows the value of an additional trip increases as the number of exclusion risks increase.

The nature of the ordered logit model that was estimated in Table 9.2 is such that the relativities across exclusion risk levels shown in the right panel of Figure 9.2 apply to all the implicit monetary values shown in Table 3, not just to trips. Hence, if an analyst wanted to examine the monetary value of increasing bridging social capital among people facing 2 or 3 exclusion risk factors, then the value ratios reflected in Figure 2 (right panel) can be applied to the Bridging Social Capital values shown in Table 3 (provided the changes in Bridging Social Capital are sufficient to move someone between category levels).

Figure 9.2: Variation in the value of additional trips, against household income and exclusion risk level



9.5 What are we valuing when we value additional trips?

The 'rule-of-a-half' in transport appraisal values benefits to all added trips resulting from transport improvements at half the savings in generalised travel costs per trip that are expected to accrue to pre-existing trips (base traffic). However, Stanley et al. (2011a) pointed out that the value of an additional trip, where the change is from a low number of daily trips (typically around 3 to 4) and valuation is in a context of reducing risk of social exclusion, was about three to four times the value implied by applying the 'rule-of-a-half', where valuation is essentially concerned with an aggregate change in numbers of trips. They suggested that this difference is because additional trips to those at risk of exclusion are essentially non-marginal and should include the value of the additional activity undertaken.

Further thought on this issue of value suggests a second likely contributor to the higher value of additional trip making that emerges in exploring exclusion risk. Social exclusion creates costs for both the excluded person and also for the wider community (Wilkinson and Pickett 2017), as reflected in the purpose of this research report. Those who are socially excluded commonly have a higher risk (than those who are more included) of being unemployed, of having poorer health (mental and physical), of being less socially connected and some will be more likely to engage in crime and/or substance abuse, with consequential costs for the wider economy, the health and justice systems, possibly compounded by the adverse impact of multiple disadvantages within a neighbourhood (Baumeister et al. 2005). There is thus another important class of benefit potentially available from enabling those at risk of mobility-related social exclusion to engage more fully in society: social exclusion externality benefits. These are the major focus of this report.

Social exclusion externalities associated with transport services, or a lack thereof, are occasionally recognised in general terms (e.g., PTEG 2013) but we are not aware of any research that has systematically sought to identify such factors and value their magnitude. For example, if bus services in outer Melbourne or a Victorian regional town were improved, what might this do to reduce mobility-related social exclusion and what flow-on reductions in social exclusion externalities (lower societal costs) might be expected?

The current paper shows that the higher the levels of household income, social capital (bonding and bridging) and/or sense of community at a personal level, the more trips a person undertakes and the more advantaged the neighbourhood in which a person lives, the less likely that person is to be at risk of social exclusion and, by extension, the lower the likely consequential exclusion external costs. With all the aforementioned influences on personal exclusion risk modelled in this paper, it seems reasonable to conclude that gains on those variables, such as trips, will flow on to lower exclusion levels and external costs – similar to the concept of agglomeration economies flowing from transport improvements, but with a social focus. As well as showing value to the individual, the authors suggest that the high implicit value of an additional trip demonstrated herein is also picking up some (unidentified) part of the external costs of exclusion, the personal and societal costs moving in concert: the impact/value is not confined to the at-risk person. There is further discussion of this point in Section 11, where the report's conclusions are set out, since it is a critical part of the research.

9.6 Conclusions

Trip making, or the capacity to be mobile, reduces risk of social exclusion and additional trip making has been shown to have high value in this context. Prior research has quantified the value of such additional trip making solely through data collected at the individual level, not considering the potential influence of the neighbourhood in which a person lives on their risk of exclusion and, if the neighbourhood effect is significant, how this might impact on the value of additional trip making. This paper seeks to narrow that gap by including a measure of neighbourhood disadvantage as an influencing factor on risk of social exclusion.

The paper shows that neighbourhood disadvantage in Melbourne, at postcode level, is a significant additional explanatory variable for risk of social exclusion, alongside influences such as trip making, social capital, sense of community and household income. However, neighbourhood disadvantage only provides a small contribution towards explaining risk of social exclusion, beyond that from the variables included in Stanley et al. (2021a) associated with individual-specific influences. Also, because of the composite nature of the neighbourhood disadvantage variable used herein, finding that it makes a small but significant contribution to exclusion risk does not easily lead to identification of suitable specific neighbourhood scale policy interventions.

A possible explanation for the small contribution of neighbourhood characteristics to increasing the level of social exclusion can be found in the work of Mitchell and Campbell (2011). The authors explain that highly excluded families have extremely impoverished social economies, in that their efforts and competencies are focused on survival, rather than building social networks and they exclude themselves from community life. Poverty, unemployment, social isolation, mental illness and substance abuse risk loss of family and friends, and perpetuating exclusion. Personal/household characteristics are what increase exclusion risk for such people, rather than the neighbourhood. A policy focus on factors increasing exclusion risk at the individual level, such as improving trip making opportunities by providing better public transport services, is thus likely to be more helpful than neighbourhood level interventions *per se* in reducing exclusion risk for such people (Murie and Musterd 2004). However, as Lupton (2003) and Knies et al. (2020) conclude, spatial concentrations of at-risk individuals suggest the need for a spatial focus too, even if neighbourhood effects seem to be relatively small.

Importantly, the inclusion of neighbourhood disadvantage, as measured herein, does not reduce the potential value of transport initiatives to reduce social exclusion. Additional trips are still valued highly, at a mean sample value of $20.40 herein, which is consistent with the range of values derived in Stanley et al. (2011a, b, 2021a) for metropolitan Melbourne (2008 prices).

The analysis has found that, in terms of reducing risk of mobility-related social exclusion, the value of additional trips increases as the number of exclusion risk factors increase. Conversely, the value of an additional trip has been shown to fall as household income increases. A policy focus on transport initiatives to reduce exclusion risk should preferably use values for additional trips that are based on different exclusion risk levels in appraisal work, rather than trip values based on relative household income levels. A challenge here, however, is that identifying the number of exclusion thresholds confronting individuals (or households), as measured herein, requires bespoke surveying. This is costly and is seldom possible, whereas data on household income is usually widely available, certainly on a spatial basis. For application purposes, given the difficulty in bespoke surveying, the authors conclude that using household-income based values for additional trips for transport appraisal work is a practical approach. This has the advantage of aligning with other income-based equity-weighting work sometimes used in cost-benefit analysis. Development of measures of individual risk of social exclusion that do not rely on bespoke surveys

would assist application of trip values that reflect such exclusion risk.

Importantly, the authors suggest that the value of additional trips as estimated herein, in a context of reducing risk of social exclusion, is likely to be picking up some of the savings in the external costs of social exclusion that will follow such increased trip-making, such as costs associated with crime, mental and physical health, economic output and productivity. This helps to explain why the trip values in question are considerably higher than is implied by the rule-of-a-half as conventionally applied to additional trips. Further research on this subject is encouraged. The external costs of social exclusion, and how these can be reduced by improved transport provisions, which in turn reduces negative neighbourhood influences, is a grossly neglected area of transport research, which promises many future PhDs.

Data availability limited the possible indicators of neighbourhood disadvantage that could be used in this research to postcode level. Future research should explore what impact smaller spatial scaling of neighbourhoods might have on findings and how the inclusion of a wider range of neighbourhood conceptions might impact on resulting monetisation of influencing variables. Work to identify individual risk of social exclusion that relies less on bespoke surveys, is also a priority, for identification of target groups for policy interventions and to evaluate the merits of those interventions, using monetary values like those derived herein.

10. Case studies[14]

10.1 Context

Stanley et al. (2021a) recently imputed monetary values to changes in trips, a range of wellbeing and social capital variables, together with sense of community, as these influence the risk of social exclusion. The first derivation of such values extends back a decade or so (Stanley et al. 2011a, b) but it appears to be only in recent times that the resulting value of additional trip making has been used in major government project appraisal. For example, the KPMG assessment of the Victorian Government's proposed Suburban Rail Loop through middle Melbourne, the largest infrastructure project ever proposed in Victoria, recognised the potential importance of this initiative for social inclusion and included trip values from Stanley et al. (2011a) for imputing inclusion benefits to the project (KPMG 2021).

This section of the report demonstrates the importance of including these exclusion benefits. This section of the report uses some of the findings from preceding sections to explore whether the benefits from major urban transport spending increases are likely to differ greatly, depending on whether that spending prioritises rail (light rail), major road network improvement or provision of additional bus services, through a series of case studies. The first set of case studies are undertaken on Sydney, using modelling undertaken by Professor David Hensher and colleagues at the Institute of Transport and Logistics Studies, The University of Sydney Business School. Social inclusion benefits are a focus of these case studies (Stanley et al. 2021b). The second case study is a short summary of a UK study undertaken at University of Leeds Institute for Transport Studies. That study explores the value of bus in helping to tackle disadvantage (Johnson 2016) and is a rare example of a serious attempt to explore wider societal benefits of bus service improvements.

10.2 The Sydney case studies

Growth in major infrastructure spending has been the dominant feature of Australia's transport landscape in recent years. For example, annual average capital expenditure by the Victorian State Government over the four-year budget period from 2021-22 will be more than four times the 10- year average to 2014-15 (Victorian Government 2021), with transport the major component.

NSW has also had a rapid growth in its infrastructure spending, with the annual average for the four-year budget period from 2021-22 nearly double that from 2013-14 to 2016-17 (New South Wales Government 2021). Transport accounts for two-thirds of the NSW capital budget and urban transport spending has been a critical focus of infrastructure spending growth.

Nationally, the total value of road and rail projects being built across Australia exceeded $120 billion for the first time in March 2020, having fluctuated around $40-60 billion between 2007 and 2016 (Terrill 2021a). Terrill notes that most of the work is now being done on projects of $1 billion or more, with average project size having doubled in the last decade. Such spending programs have been partly about overcoming backlogs associated with rapid population growth. Melbourne, for example, added 475,000 (+12%) to its population size between the 2011 and 2016 census dates, and Sydney added 430,000 (+10%). These are high population growth rates for cities of 4-5 million population with a high level of economic development.

However, the large and growing transport infrastructure expenditures in Australia are frequently not supported by publicly available economic assessments of alternatives, including assessments that explore different ways of achieving intended outcomes. In Victoria's case, this concern has recently been highlighted by the State's Auditor-General, who found that:

> *"The absence of a transport plan as required by the [Transport Integration] Act, during a decade of unprecedented investment in transport infrastructure, creates risks of missed opportunities to sequence and optimise the benefits of these investments to best meet Victoria's transport needs."*

(VAGO 2021, p. 1)

This paper explores whether the benefits from major urban transport spending increases are likely to differ greatly, depending on whether that spending prioritises light rail, given growing interest in this mode and several new services recently developed in Australia, major road network improvement or provision of comprehensive additional bus services. It does this through a series of case studies based on the Greater Sydney Metropolitan Area (GSMA), making use of the Institute of Transport and Logistics Studies' MetroScan model (Hensher et al. 2020 and Appendix B of the current report). MetroScan is the most sophisticated strategic integrated land use, transport and economic system evaluation model in Australia, with the capability of exploring dynamic interactions between transport improvements, residential locations and job

[14] The Sydney case studies presented in this section have been published in a recent edition of Research in Transport and Business Management (Stanley et al. 2021b).

locations, among other things, for both passenger and freight movements.

One particular focus of the case studies is an assessment of the extent to which the different initiatives might contribute to reducing risks of mobility-related social exclusion. This has been an area of concern for transport policy makers, planners and researchers for about two decades, dating mainly from the time of the Social Exclusion Unit's pioneering work in the UK (SEU 2003). However, formal analytical tools that involve benefit monetisation are still in their infancy, even though it is now a decade since the value of additional trip making to those at risk of social exclusion was demonstrated (Stanley et al. 2011a, b). The current paper shows why consideration of potential inclusion benefits can be crucial for project assessment outcomes, underlining the importance of taking it more seriously in appraisal. The heightened impact of COVID-19 during 2020 and 2021 in areas of social disadvantage in Sydney and Melbourne reinforces the importance of this issue.

Four Sydney case studies have been selected for comparison purposes: Parramatta Light Rail (Figure 10.1); M4 Outer Motorway upgrade (Figure 10.2); a doubling of the service frequencies of a large proportion of Sydney's urban route bus services, focussed in middle and outer suburbs (Figure 10.3, top panel) – this case study is called Bus Service Additions (1); and, a doubling of bus service frequencies in Sydney's outer west, an area of relative socio-economic disadvantage – this initiative is called Bus Service Additions (2) (Figure 10.3, lower panel).

Bus Service Additions (1) and (2) include upgrades to both trunk and local services, with the former accounting for about three quarters of route lengths. Analysis of the benefits and costs of Bus Service Additions (1), which are widespread, and the study's interest in the linkages between major transport improvements and the possibility of reduced risks of social exclusion, led to the more spatially focussed doubling bus service frequencies in Bus Service Additions (2), targeting Sydney's Outer West. As identified in Section 10.2, and shown in Figure 10.5, this part of Sydney has higher concentrations of people who are more likely to be risk of mobility-related social exclusion.

Light Rail is a relatively new mode in Sydney[15], accounting for only 12 million (unlinked) trips in 2019-20. By way of comparison, train plus metro accounted for 300m unlinked trips and bus a further 230m unlinked trips in that year. A major Sydney public transport network addition, Parramatta Light Rail Stage 1 will connect Westmead to Carlingford via the Parramatta CBD and Camellia, with its two-way track spanning 12 kilometres. The route is expected to open in 2023, with an estimated capital cost of $2.4 billion (Parramatta Light Rail - Infrastructure Pipeline). The NSW Government suggests that, *By 2026, around 28,000 people will use Parramatta Light Rail every day and an estimated 130,000 people will be living within walking distance of light rail stops* (Parramatta Light Rail | Parramatta (nsw.gov.au)). A subsequent Stage 2 will connect the Parramatta CBD to Olympic Park. Detailed discussion of the study area and potential impacts of Light Rail is set out in reports such as HillPDA Consulting (2017) and Jacobs (2017).

For consistency of scale with the Parramatta LR project, the upgrade to the M4 Outer Motorway was chosen as a representative major road project. This is essentially a road widening project of around 37 kilometres in length, from the M4 East to the Nepean River, as shown in purple in Figure 11. 2. This project is also estimated to have a capital cost of around $2.4 billion.

This paper explores some of the most important prospective strategic transport and land use impacts of the four major transport initiatives. Section 2 of the paper explains the derivation of the social exclusion rating scale that is applied across 80 zones in Sydney, as part of each of the four project assessments. Section 3 discusses predicted impacts of the initiatives on trip making, while Section 4 considers impacts on major government revenue flows. Most benefits are costs are discussed in Section 5 and Section 6 presents an assessment of social inclusion benefits. Section 7 sums up the overall assessments and Section 8 presents the paper's conclusions.

[15] Although there was widespread tram service provision up to the late 1950s, and after that until recently there was a short light rail track in the inner area of Sydney going to the inner West. The CBD light rail commenced operations in the middle of 2020, extending to the Eastern Suburbs.

Figure 10.1: Parramatta Light Rail, Stage 1 (Source: Maps | Parramatta (nsw.gov.au))

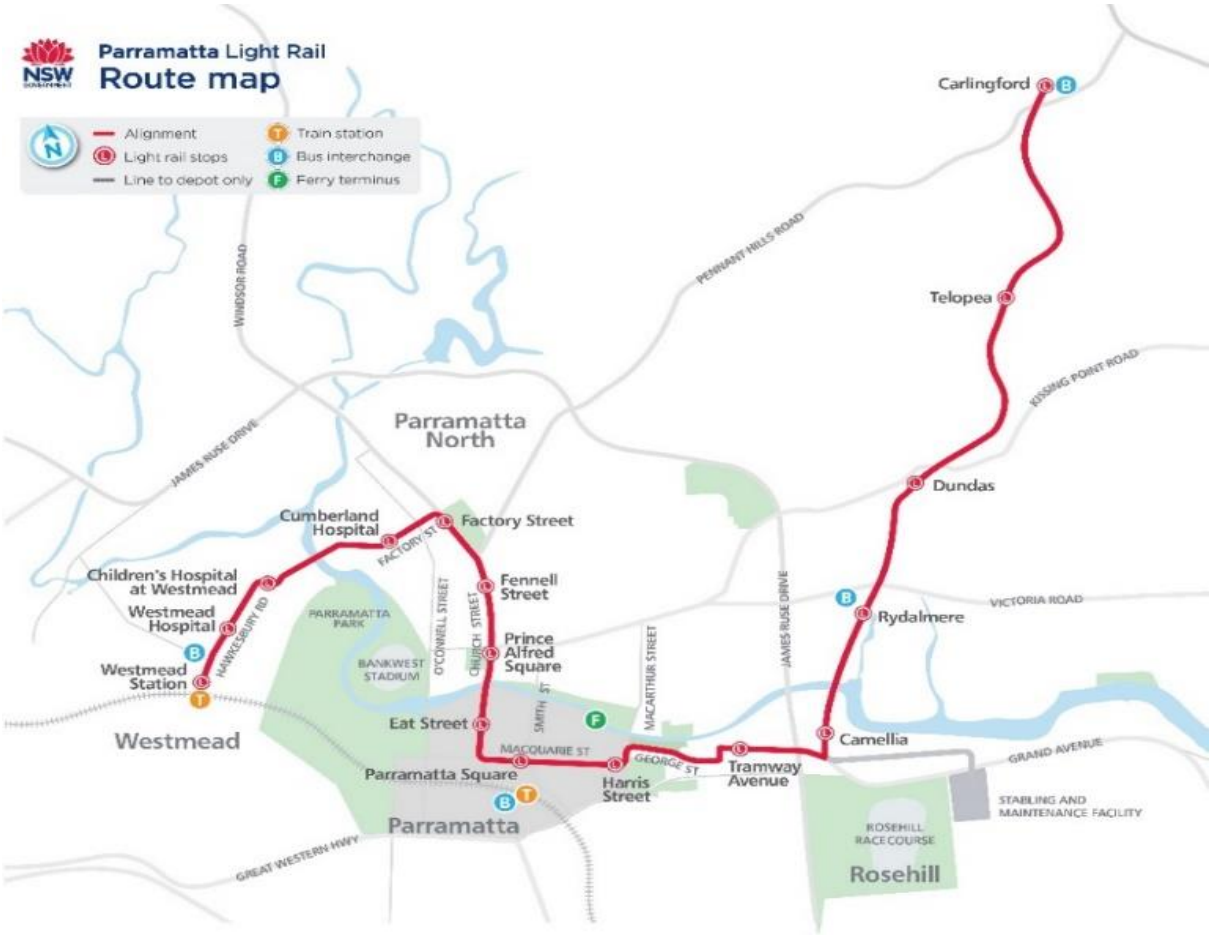


Figure 10.2: M4 Outer Motorway
(Source: Western Sydney road alignments - M4 Motorway (Sydney) - Wikipedia)

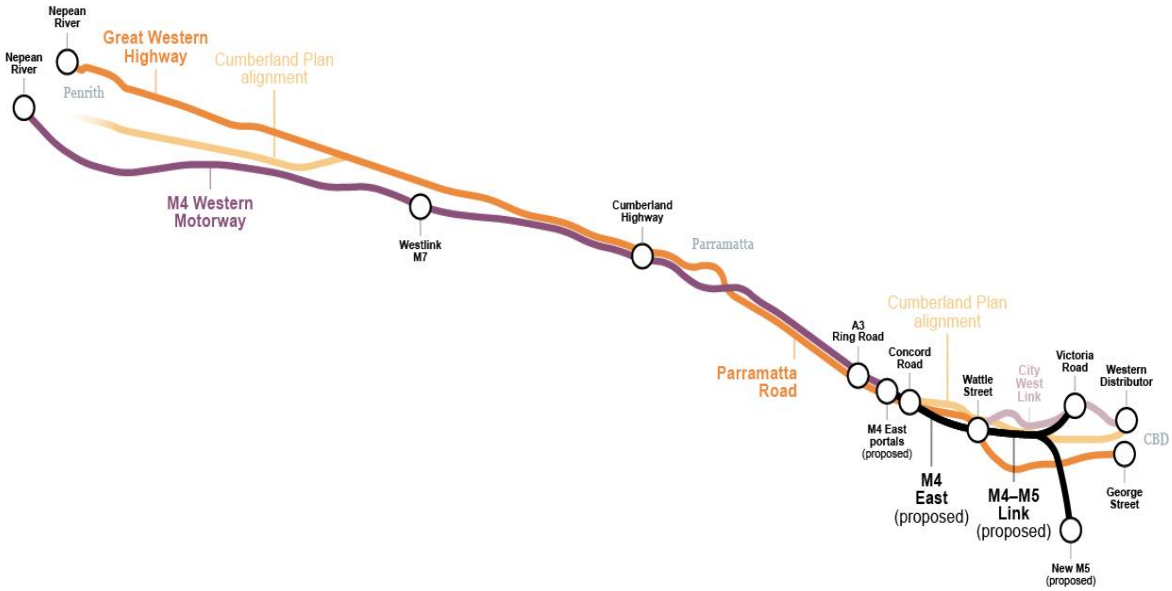
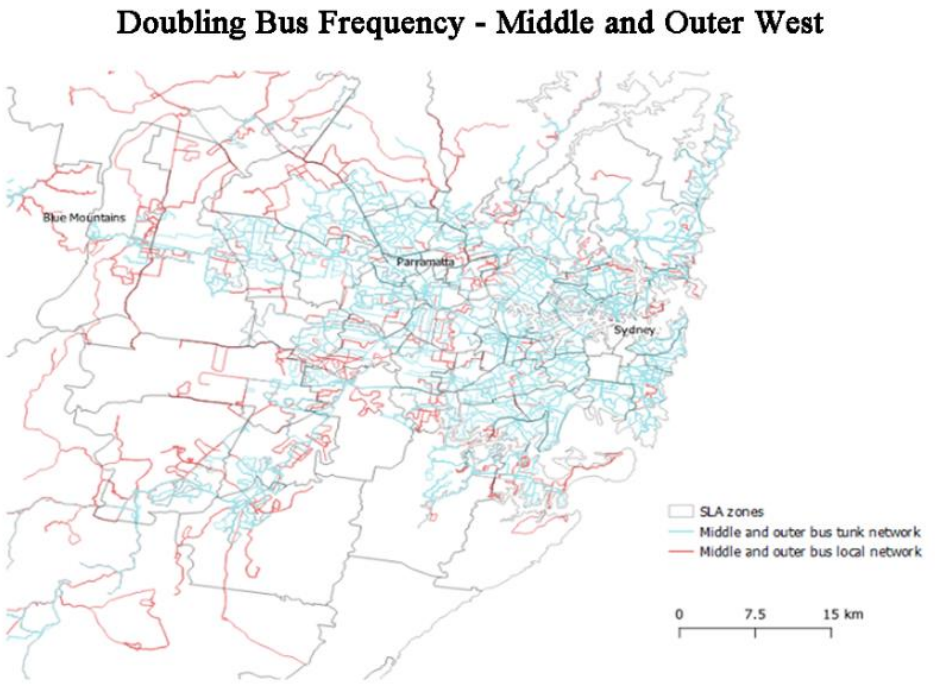
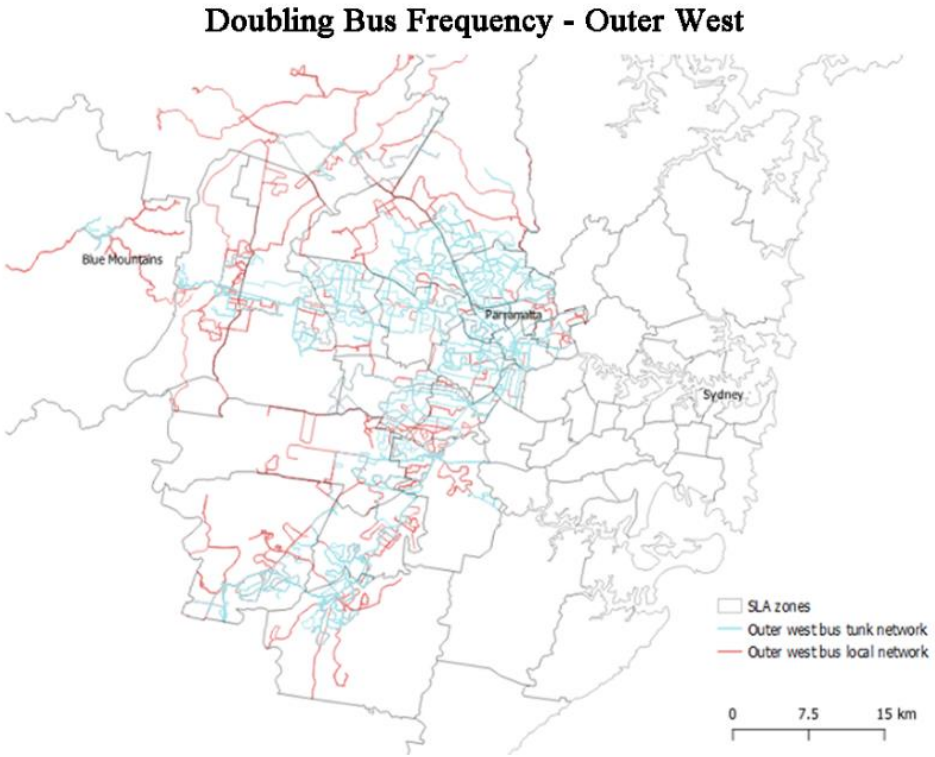


Figure 10.3: Service improvement areas for Bus Service Additions (1) and (2)

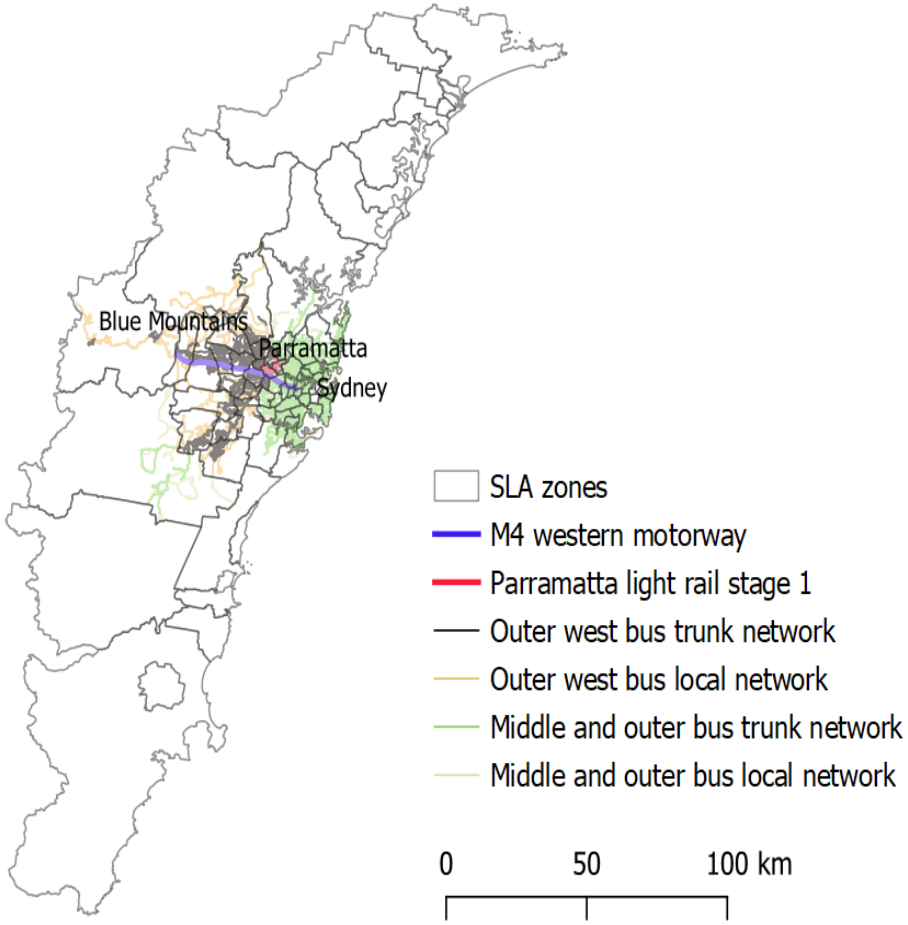




10.3 The study area and risk of mobility-related social exclusion

The study area for this analysis was defined as the Greater Sydney Metropolitan Area (GSMA), stretching from Newcastle to Wollongong (Figure 10.4), with a wide range of socio-economic and traffic data being assembled for this area. Given that an important focus of this report is mobility-related social exclusion, Figure 10.5 shows the authors' broad categorisation of the study area in terms of likelihood of mobility-related risk of social exclusion, from 'lowest risk' to 'most risk', based on readily available zonal data (largely census data). This means that the approach is replicable across different Australian jurisdictions. However, it has the disadvantage of socially excluded people being lost amongst zonal averages.

Figure 10.4: The areas where the four projects are located within Sydney



Categorisation of the relative risk of people from each of the 80 study area zones being at risk of mobility-related social exclusion, as shown in Table 10.5, was determined by how each zone measures up in terms of four indicators:

- The proportion of its population aged 0-19, since children and youth tend to be more reliant on others, and on public transport (PT), to access opportunities (Currie, Stanley and Stanley 2007).
- The proportion of its population aged 75 or more, since older people also tend to be more dependent on others, and on PT, for accessibility (Hensher 2007; Alsnith and Hensher 2003).
- (Median) family income, since those with higher incomes are more readily able to purchase mobility solutions. This was a measure of exclusion risk in Stanley et al. (2011a, b).

- Unemployment since this is a common indicator of disadvantage and of risk of social exclusion (Stanley et al. 2011a, b).

Each of the 80 Sydney study area zones was ranked on each of these indicators, each ranking then being divided in to four quartiles (i.e., 20 zones in each), representing from 'least risk' to 'most risk' of mobility-related social exclusion. Zones in the least risk quartile on each of the four indicators were (somewhat arbitrarily) given a score of 0, with the next quartiles then scored as 2, 3 and 4. The step from 0 to 2 (missing 1) was adopted to accentuate the gap between zones that are least likely to be at exclusion risk and zones where risk is more likely (given the selected indicators). The resulting scores were summed across the four indicators, (maximum possible score = 16). Zones were then put into four groups, based on their aggregate score, with:

- scores from 0 to 5 = lowest risk of mobility-related social exclusion (= 14 zones);
- 6-9 = low risk (22 zones);
- 10-11 = moderate risk (= 22 zones); and
- 12=16 = most risk (22 zones).

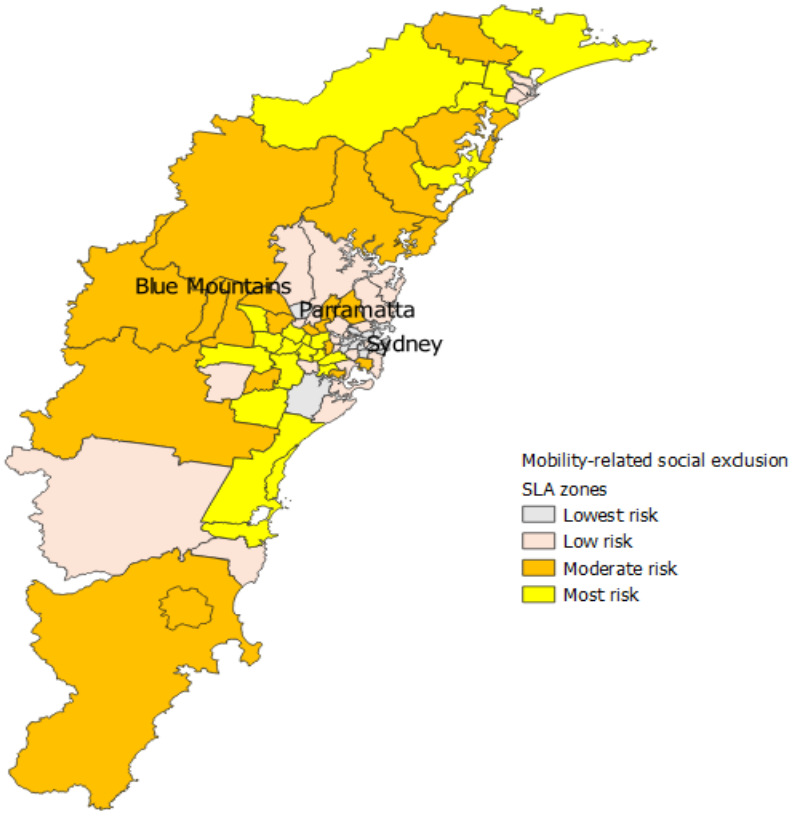
The zonal categorisations shown in Figure 10.5 are a broad way of identifying areas in which seeking transport solutions to reducing social exclusion risk might be a relatively high priority. It also provides some insight into whether those who benefit or lose from transport initiatives that are being assessed are likely to be at greater or lesser risk of mobility-related social exclusion. Such areal categorisation thus provides one way of introducing an equity perspective on the relative merits of the initiatives under examination.

It is noteworthy that there is a high positive correlation between the unit values of the social inclusion index developed herein (which range between 0 and 16) and the incidence of COVID-19 by LGA across Sydney. The higher the social exclusion index (risk level) the greater the incidence of COVID-19, as reflected in the following relationship:

$$Y = 4.4278e^{0.2304x} (R^2 = 0.78815) \quad (1)$$

where Y = COVID-19 cases in Sydney recorded up to 9 August 2021, and X = the social inclusion index derived herein. This link to health risks illustrates just one of the reasons for seeking to do something about reducing social exclusion in areas of higher risk.

Figure 10.5: Sydney zones categorised by mobility-related risk of social exclusion (authors' assessment)



Stanley et al. (2011a, b) showed that additional trip making by those at risk of mobility-related social exclusion has considerable benefit, with the value of that benefit increasing as household income declines. Zones coloured yellow in Figure 10.5 would thus be relatively high priorities for improved mobility opportunities for those interested in reducing risks of mobility-related social exclusion and zones coloured brown are also deserving of close consideration from this perspective. These more at-risk zones are mainly concentrated to Sydney's west, south-west and, with some exceptions, around the region's northern and southern extremities (around Newcastle and Wollongong). The central/inner area and inner/middle north shore are rated as being at lowest risk.

10.4 Predicted impacts of initiatives on trips

Impacts on trip making are a central part of transport initiative assessment. Table 10.1 sets out MetroScan's estimated trip numbers by mode, for 2023 and 2033, with and without each of the four initiatives under assessment (treated separately). For the Parramatta Light Rail (PLR), key points to note are as follows.

- The PLR is predicted to lead to a small net increase in the total number of trips across Sydney: 3.0 million in 2023, rising to 7.1 million in 2033.
- In the base case (no PLR but current committed transport improvements in place), annual trips as car driver alone are predicted to increase by 658 million from 2023 to 2033 and car passenger trips by 357m. However, with PLR this increase is predicted to slow to 642m for car driver trips and 351m for car passenger trips, a total reduction of 22m trips as car driver or car passenger in 2033 (numbers are not shown in Table 10.1), as the PLR attracts car users to switch to public transport (PT).
- Bus is predicted to lose passengers, by around 1.4m trips in 2023, rising to 3.4m fewer trips in 2033, showing that there is a degree of competition between these PT modes.
- Total annual train trips, which includes the PLR, are predicted to increase by 19.2m in 2023 and 47.1m in 2033 with the PLR in place, as compared to without that development.

As well as car trips being predicted to fall a little with the PLR, vehicle kilometres of car travel are also predicted to fall marginally, by 0.24% in 2023 and 0.53% in 2033 (not shown in Table 10.1). The reduced car traffic volumes, together with increased economic output stimulated by the PLR project (discussed below), are then projected to lead to a small increase in road freight volumes, of around 0.4%.

In contrast, the M4 upgrade is predicted to lead to a small decline in total trip numbers, by 1.2m in 2023 and 1.5m in 2033 (-0.02% in each year). Table 10.1 shows that car drive alone trips are predicted to increase, by 3.0m in 2023, rising to 3.6m additional trips in 2033. Part of this increase comes from people switching away from PT. Bus is predicted to lose 0.8m trips in 2023 and 1.0m in 2033, with train losing 2.2m in 2023 and 2.7m in 2033. Less expected is the predicted drop in car passenger trips, estimated to fall by 1.2m in 2023 and 1.4m in 2033, MetroScan predicting that the increased ease of travel with the Motorway upgrade will not only attract people away from PT but will also encourage more people to drive themselves, rather than going in someone else's car. Total car kilometres travelled are also predicted to increase marginally (not shown in Table 10.1).

Because of its widespread nature and relative scale, the extensive doubling of bus service frequency included in Bus Service Additions (1) (BSA1) is predicted to increase bus patronage substantially, by 29.1m trips in 2023 and 54.6m in 2033. Train patronage is predicted to fall a little, by around 4m trips in 2033, again suggesting some competition between bus and train. Importantly, however, car drive alone trips are predicted to fall significantly, much more than in the case of the PLR project. Some 14.6m fewer car drive alone trips are predicted in 2023 and 26.9m fewer in 2033, with car passenger trips also falling. The total number of trips by all modes, among the four projects assessed, has its biggest increase under BSA1, with 10.6m more trips in 2023 and 19.7m in 2033.

The more focussed doubling of bus service frequencies in Bus Service Additions (2) (BSA2) is predicted to increase bus patronage by 11.6m trips in 2023, increasing to 22m in 2033. Train trips are predicted to decline marginally but a substantial reduction in car drive alone trips is predicted in both 2023 and 2033 (6.3m and 11.7m trips respectively), suggesting a solid switch from car to bus. This was also the case for BSA1. Total trip numbers are predicted to increase by 4.4m in 2023 and 8.2m in 2033, reflecting the progressive roll-out of the service doubling assumed for this option (and for BSA1).

10.5 Predicted impacts on major revenue flows

The changes in travel tasks associated with the four initiatives are predicted to lead to changes in state government and federal government revenue collections and in toll road revenue collections, all of which are relevant to an assessment of project economic merit. This paper includes estimates of changes in State PT fare revenue collections and in Federal Government fuel excise collections, together with changes in toll road revenues. While these revenue flows are partly about who gains and who loses (benefit/cost incidence), they are also reflective

of net value changes that reflect economic benefits and costs.

As shown in the bottom sections of Table 10.1, the PLR is predicted to lead to an increase in total NSW state government fare revenue collections of $48 million in 2023, increasing to $118m in 2033. For translating these changes to benefit/cost estimates for purposes of cost benefit analysis, the change in state fare revenue collections is assumed to remain constant at this 2033 level (reflecting forecasting humility!). This approach is taken for all annual benefit/cost flows[16]. In present value (PV) terms over the 2021 to 2053 period (2019 prices; 2021 PVs; 7% discount rate), future increased fare revenues are estimated to be worth $1.0b. This is a solid number, relative to expected project operating cost, suggesting a better than break-even outcome on operating expenditures, as shown subsequently in Table 10.4.

Conversely, in the PLR case, federal fuel tax revenues are predicted to fall by $8m in 2023 and by $21m in 2033, due to reduced car use. This excise loss has a PV of $182m. Small losses in toll revenue collections are also shown in Table 10.1 and represent losses to relevant owners. Table 10.4 shows the estimated PV of the toll revenue loss at $6m.

While PLR is predicted to boost PT revenue but reduce federal fuel excise collections, the M4 project is predicted to have the reverse effects. NSW PT fare revenue is predicted to fall by $9.4m in 2023 with the M4 project in place, increasing to $11.6m less fare revenue in 2033. However, Federal fuel excise collections are predicted to increase marginally (<$1m annually), reflecting increased road traffic volumes following the M4 upgrade.[17]

Toll revenue is also predicted to increase marginally (<$100K p.a.). In PV terms, the PT fare revenue loss is estimated at $120m, while the Federal fuel excise gain is valued at $5m. The PV of increased toll revenues is estimated to be only $1m (Table 10. 4).

Doubling bus service frequencies as in BSA1 is predicted to increase PT fare collections by $112m in 2023 and $208m in 2033, reflecting the strong predicted bus patronage gains. This fare revenue boost has a PV of $1.9b (Table 1o.4). However, fuel excise collections are predicted to fall, but far less than the increase in fare revenues. Excise collections are estimated to be $13m lower in 2023 and $26m lower in 2033, with the PV of excise collections being valued at a cost of $238m (Table 10.4). Toll revenue collections are predicted to fall by a very small amount (e.g., <$20,000 in 2033).

The less comprehensive but more targeted doubling of bus service frequencies in BSA2 is predicted to increase PT fare revenue collections by $46m in 2023 and $85m in 2033, with a PV of $786m, about 40% of the increase predicted for BSA1. Federal excise collections are predicted to fall by only half as much as for BSA1 and there is little change expected in toll revenue collections.

[16] Residual values are ignored, being typically minimal at a 7% real discount rate, as used herein.

[17] Based on an ongoing full ICE petrol and diesel fleet but with electric cars this will change (Hensher et al. 2021). The NSW government has proposed to remove stamp duty on electric cars and will impose 2.5c/km from 2027, or once electric car sales have reached 30% of new car sales. *Source:* https://www.smh.com.au/national/nsw/nsw-to-abolish-stamp-duty-on-electric-cars-in-an-effort-to-boost-uptake-20210619-p582g4.html

Table 10.1 Predicted impacts of the three initiatives on annual trip numbers in the study area (million trips) and on key revenue streams ($m; 2019 prices)						
			Changes in trip numbers/revenue flows			
Indicator	Year	Base number	Parramatta LR	M4 addition	Bus service additions (1)	Bus service additions (2)
Car drive alone trips	2023	3063m	-10.5m	+3.0m	-14.6	-6.3
Car with passenger trips	2023	1651m	-4.3m	-1.2m	-2.3	-0.7
Bus passenger trips	2023	195m	-1.4m	-0.8m	+29.1	+11.6
Train passenger trips (incl. LR)	2023	253m	+19.2m	-2.2m	-1.7	-0.2
TOTAL TRIPS ALL MODES	2023	5161m	+3.0m	-1.2m	+10.6	+4.4
Car drive alone trips	2033	3721m	-25.7m	+3.6m	-26.9	-11.7
Car passenger trips	2033	2008m	-10.9m	-1.4m	-4.2	-1.0
Bus passenger trips	2033	234m	-3.4m	-1.0m	+54.6	+22.0
Train passenger trips (incl. LR)	2033	333m	-47.1m	-2.7m	-3.9	-1.1
TOTAL TRIPS ALL MODES	2033	6295m	+7.1m	-1.5m	+19.7	+8.2
State fare revenue gain	2023	$1482m	+$48m	-$9.4m	+$112m	+$46m
	2033	$1860m	+$118m	-$11.6m	+$208m	+$85m
Federal excise revenue gain	2023	$3302m	-$8m	+$0.3m	-$13m	-$7m
	2033	$4014m	-$21m	+$0.5m	-$26m	-$13m
Toll operator revenue change	2023	$867m	-$0.1m	+$0.1m	-$0.0m	+$0.0m
	2033	$1057m	-$0.8m	+$0.1m	-$0.0m	+$0.0m

10.6 Key benefits and costs

User benefit estimates are critical to assessing the economic worth of major transport initiatives, typically being the primary rationale for those initiatives. MetroScan (Hensher et al. 2020) enables estimation of these benefits as increases in trip maker consumers' surplus, which represents the difference between what people would be willing to pay for the trips they make and what they actually pay, based on changes in constituent elements of generalised travel costs[18].

Table 10. 2 sets out user benefit estimates for 2023 and 2033, for public transport (PT) users, car users and freight traffic, with totals subsequently being shown in PV terms in Table 10.4. Appendix A details the key parameter values used in this assessment. User benefits in Table 10.2 are calculated in the conventional (rule of a half) way, derived from changes in generalised cost, with base traffic being accorded a full unit benefit per trip and generated traffic half this trip benefit.

For projects that are of similar scale in capital cost terms, the M4 is estimated to produce about double the level of user benefits for car users in 2033 ($533m) that PLR does for PT users in that year ($275m). Doubling bus service frequencies in BSA1 produces similar scale benefits for PT users in 2033 ($521m) as the M4 does for car users in that year, showing the value of widely spread bus service enhancement. The loss of road space for car use in the PLR case is estimated to cause large costs for car users, which exceed the estimated benefits created for PT users. The reduced scale of bus service improvements in BSA2 is estimated to generate PT user benefits of about half the scale estimated for BSA1 in 2033. However, the concentration of BSA2 in middle and outer western and south-western areas is predicted to have a considerably smaller adverse impact on car users than the more widespread BSA1.

[18] The Full Generalised Cost for Public Transport includes public transport fares plus time costs using the value of travel time saving (VTTS) and the value of reliability (VoR). The Full Generalised Cost for Car includes fuel and other extra vehicle costs (e.g., toll, parking, and registration) and time costs using VTTS and VoR. The Total End Use Generalised Cost is the weighted average of the former two generalised costs, weighted by the total annual numbers of trips made by public transport and car. VTTS and VoR values we applied are included in Appendix A.

Table 10.2 Estimated transport user benefits from three initiatives ($m; 2019 prices)					
User category	**Year**	**Parramatta LR**	**M4 Additions**	**Bus service additions (1)**	**Bus service additions (2)**
PT user benefits	2023	115	11	469	142
	2033	275	14	521	250
Car user benefits	2023	-185	438	-136	-38
	2033	-426	533	-240	-63
Freight movement	2023	78	92	216	104
	2033	103	136	225	116
TOTAL USER BENEFITS	**2023**	**8**	**541**	**549**	**208**
	2033	**-148**	**683**	**506**	**302**

Freight traffic is estimated to gain substantially from all four initiatives, from improved road space availability. Addition of freight benefits from the PLR improves its total user benefits considerably but not sufficiently for those benefits, in aggregate, to be positive in 2033. Importantly, however, Table 10.4 subsequently shows that, when social inclusion benefits from additional trip making are recognised (an added user benefit, discussed in Section 6), the economic performance of the PLR improves very considerably, showing a good net economic outcome.

In a result that will surprise many, the comprehensive doubling of bus service frequency in BSA1 is predicted to be the most valuable of the four initiatives for freight, which is largely because of the predicted fall in car use associated with this widely spread improvement in bus service levels.

Australia is one of the world's highest per capita emitters of greenhouse gases and transport is a major contributor to those emissions (18% of total emissions in 2018). Total transport sector emissions were just over 100Mt in 2018 and road transport accounts for around five out of every six tonnes of these transport emissions. The performance of the road transport sector will thus be a key influence on how well Australia can contribute to international efforts to limit global warming.

The impact of the four projects on GHG emissions was assessed on two bases: first, an estimate that assumes no change in emissions intensity over the analysis period – a base case – with Table 10.3 setting out emissions predictions aligned with this base case; and second, a policy driven alternative that assumes emissions intensities improve by around 5% annually, as Australia reacts to inevitable. International pressure to substantially improve its emissions performance. The impact of this tougher stance is reflected in the text, and subsequently in Table 10.4, but not in Table 10.3, which only sets out the base case estimates.

Table 10.3 shows that, in the base policy environment, the PLR is predicted to lead to a reduction of ~11,500 tonnes CO_2-e in 2023, this reduction increasing to 59,500 tonnes in 2033. Total emissions reduction over the period to 2053 is estimated at about 1.6 million tonnes, with a PV of $30m (Table 10.4). Because this assessment excludes changes in emission intensity, it is basically dependent on changes in travel volumes by vehicle type. If a policy-driven 5% annual improvement in overall transport emissions intensity was to be realised, the reduction in total emissions flowing from the PLR would be reduced to 650,000 (because the wider policy environment has reduced the GHG emissions available to be mitigated), with a benefit PV in this case of $15m (Table 10.4).

In the base GHG assessment, doubling bus service frequencies as in BSA1 is expected to reduce GHG emissions by a similar amount to that predicted for the PLR over the period to 2053 (1.4Mt compared to 1.6Mt for the PLR), implying a broadly similar monetary value for GHG emissions reduction benefits (Table 10.4). This benefit value halves if the background policy environment delivers a 5% annual reduction in road transport GHG emissions. BSA2 effectively halves the GHG impact predicted for BSA1.

In contrast, the M4 is predicted to be associated with an increase in GHG emissions and associated costs in both 2023 and 2033 in the base projection. Over the period to 2053, in an unchanged GHG policy environment, total GHG emissions are predicted to increase by ~850,000 tonnes, with a PV cost of $18m (Table 10.4). This cost reduces to $12m in a policy environment that leads to 5% annual reductions in base GHG emissions.

The NSW Department for Transport (TfNSW) price of $62.79 (June 2019) per tonne of CO_2-e, as shown in Appendix A, was used to value emissions reductions (TfNSW 2020). This value might be seen as conservative, in light of the conclusions of the High Level Commission in Carbon Prices, co-chaired by Professor Joseph Stiglitz and Lord Nicholas Stern, which proposed carbon prices of $US40-80/tonne of CO_2-e in 2020, rising to $US50-100 in 2030 (Carbon Pricing Leadership Coalition 2017). $A62.79 is at the low end of this range.

Over 600 Australians are estimated to have died because of transport-related air pollution in 2015, a 2020 Draft Regulation Impact Statement showing strong economic returns if EURO VI emissions standards for heavy vehicles were to be implemented in Australia (DITRDC 2020). That assessment suggests that NOx emissions in 2050 could be reduced by 80%, against business-as-usual levels, and particulate emissions by 59%.

As with GHG emissions, two sets of air pollution benefits/ costs were developed for the current assessment: a base case in which emissions per vehicle kilometre are assumed

to be unchanged; and a policy driven setting in which air pollutant emissions are progressively reduced, to be 80% lower by 2050, in line with the DITRDC (2020) estimate for NOx from heavy vehicles. This presumes that further improvements in PM emissions will be achievable beyond those embedded in the EURO VI standards and that light vehicles will achieve similar improvements (e.g., via electrification). A 5% annual reduction (compounding) in air pollution costs was assumed for this setting, in accord with the approach taken for the policy driven GHG assessment.

In the base case, MetroScan predicts that there will be a small increase in local air pollution levels and associated costs in 2023 if the PLR is in operation, of around $5.8m (Table 10.3), mainly due to increased freight movements (air pollution costs attributable to freight are predicted to increase by $11.7m in that year, being partly offset by reduced air pollution costs from lower car use). By 2033, however, air pollution levels and costs are expected to become a small benefit for the PLR. In PV terms, the PLR is estimated to deliver marginal additions to air pollution costs in both the base case and the policy driven alternative (Table 10.4).

In the base case, Table 10.3 shows that BSA1 is predicted to increase local air pollution costs by $23.3m in 2023, reducing to an increase of $8.5m by 2033. As with the PLR, this is mainly attributable to increased freight traffic emissions/costs but, in this case, it is also due to more diesel bus use. The estimated PV of increased air pollution costs in this base case is $151m, reducing to $112m in the policy driven alternative (Table 10.4). Initiatives such as that by the NSW and Victorian State Governments to electrify their bus fleets is an example of how the policy driven alternative might be achieved. BSA2 is predicted to about halve the air pollution cost increase estimated for BSA1.

Table 10.3 Some transport emissions implications of the Parramatta LR project: Base emissions assumptions only

Indicator	Year	Base value	Parramatta LR	M4	Bus service additions (1)	Bus service additions (2)
CO_2 emissions base: passengers + truck	2023	16.7 Mt	-0.011Mt	+0.023Mt	+0.003Mt	-0.003Mt
	2033	20.4 Mt	-0.059Mt	+0.028Mt	-0.055Mt	-0.026Mt
CO_2 emission costs - base	2023	$1052m	-$720K	+$1.5m	+$0.2m	-$0.02m
	2033	$1279m	-$3.7m	+$1.8m	-$3.4m	-$1.7m
Local air pollution costs	2023	$5110m	+$5.8m	+$14.0m	+$23.3m	+$10.7m
	2033	$6222m	-$2.9m	+$17.2m	+$8.5m	+$4.6m

Table 10. 3 shows that the base case cost implications of the increased air pollution levels associated with the M4 project are about ten times as high as the costs of its increased CO_2 emissions for the years shown, Table 10.4 subsequently showing these increased air pollution costs amount to an estimated PV of $178m for the M4 upgrade, a significant sum. This reduces to a cost of $114m in the policy driven alternative, still a significant sum.

The MetroScan analysis assumes that Sydney's total population size will not be affected by the major transport initiatives under assessment, but that population distribution can change. With PLR in place, MetroScan predicts that residential population numbers as at 2033 will increase in the vicinity of the facility, with Parramatta Inner, Parramatta NE and Holyroyd adding a total of ~32,000. This is a little over one-third of the projected total population growth across the three zones from 2023 to 2033, which is substantial. Figure 10.6 shows predicted changes in population distribution in 2033 for each of the four projects.

In contrast, the M4 upgrade is primarily predicted to spur faster population growth in the corridor from around Parramatta to the outer west of Sydney (Figure 10.6). Thus, for example, Penrith East and West are predicted to add ~5,400 by 2033 and Blue Mountains to add 4,600, with Blacktown SE and SW adding 3,400. This suggests people are taking the opportunity provided by going faster to go further, encouraging increased urban sprawl.

Figure 10. 6 shows that the extensive doubling of bus frequencies in BSA1 is predicted to lead to more residential consolidation in inner/middle Sydney, including north of Sydney Harbour, where many parts are relatively bus dependent for public transport service. By 2033, places such as Warringah (+3684), Pittwater (+1114), Manly (+1057) and Ryde (+1103) are predicted to have notable population increases, as are Randwick (+1166) and Hills Shire (+1378). With total population numbers fixed, that means small population losses across outer areas, including extremities to the north.

Conversely, the BSA2 impact is less widespread, with residential location impacts being concentrated in the corridor from around Parramatta to the west, then extending north and south. Notable population increases are predicted by 2033 for Liverpool East plus West (+3200), Blacktown (+2100), Penrith East plus West (2000) and Fairfield (+1700). The corollary is small losses elsewhere, given the assumption of a total fixed population number.

While the analysis assumed that total population numbers at any future point in time would not change following the introduction of the major transport initiatives, total employment numbers were allowed to change, as the major transport initiatives stimulate development. MetroScan predicts net employment increases in Greater Sydney of ~16,000 by 2033 associated with introduction of the PLR (excluding construction stage effects for this project and for the M4). These are the largest gains in employment numbers predicted for any of the four transport improvements analysed. Figure 10.7 shows predicted percentage changes in job numbers in 2033 for each of the four projects. Even though the PLR is located around Parramatta, the strongest gains in job numbers associated with that project are predicted to be in inner Sydney, showing the network benefits of the project and the strong economic pull of the inner area. This implies increased effective economic density in the inner area and associated agglomeration economies (discussed below). Some outer northern and southern areas are predicted to shed a small number of jobs.

In contrast, MetroScan predicts that the M4 upgrade will not add to total job creation but will lead to some job redistribution. Figure 10.7 shows that employment gains in 2033 are predicted in the Parramatta area and corridor to the west, partly reflecting the predicted changes in population distribution, while small job losses are predicted across large parts of Sydney. The relative accessibility advantages conferred by the M4 upgrade are thus predicted to affect the distribution of jobs but this is not predicted to lead to a net increase in total employment - predicted zonal gains marginally fall short of predicted zonal employment losses at 2033 (-3330 jobs in total).

Doubling bus service frequency as in BSA1 is predicted to lead to 7420 additional jobs in 2033, which is stronger than the M4 upgrade but not as strong as the PLR. Like its predicted impact on residential population distribution, this doubling bus service frequencies is predicted to support some job consolidation in inner/middle Sydney, including north of the Harbour, with small reductions further out, particularly to the outer north and south. Numbers involved in the latter locations are small. BSA2, being smaller in scale and concentrated in lower density areas, is predicted to lead to a marginal reduction in total jobs in 2033 (-5000). Job numbers are predicted to increase around Parramatta, Fairfield, Liverpool, Penrith, Blacktown and the Hills but with some small losses in inner areas (Figure 10.7).

Discussion of changes in job locations leads to consideration of how the transport improvements under consideration change the effective economic density (EED) of Sydney and how this, in turn, flows through to changing economic productivity, through agglomeration effects. EED is a measure of the accessibility of each zone to employment in other zones, weighted by the generalised cost of movement between that zone and each other zone.

MetroScan estimates that the EED of Greater Sydney will increase by 0.398% by 2033 with the PLR in place, but the relative increase in several inner areas is larger. Figure 10.8 shows the broad pattern of changes in EED at 2033 associated with the PLR (and the other three projects), with some job relocations to more accessible locations, but also with some predicted small movement away from locations where accessibility has declined in relative terms. As noted previously, there is also a small increase predicted in total job numbers with the PLR. Figure 10.8 shows the agglomeration strength of the inner/central areas.

Conversely, MetroScan estimates that Greater Sydney's EED will decline by 0.085% by 2033 with the M4 upgrade in place, reflecting the influence of relative accessibility improvement in lower density outer suburbs. For the comprehensive doubling of route bus service frequencies of BSA1, MetroScan predicts that EED will increase by 0.203% by 2033. These gains are less than for the PLR, suggesting smaller agglomeration economies. The smaller set of bus frequency increases in BSA2 is estimated to reduce Sydney's EED by 0.127% in 2033. This reflects the pattern for the M4 upgrade, with the focus on outer suburbs reducing agglomeration tendencies. Figure 10.8 shows the predicted changes in EED across Sydney for this bus frequency increase, with inner areas again the main winners.

Drawing on predicted changes in EED at the zonal level (80 zones), agglomeration economies were estimated for each of the four initiatives in line with the UK Department for Transport Webtag approach (DfT 2020), using the formula set out in Stopher and Stanley (2014), as follows:

$$\Delta \text{ GDP} = [(EED_{after}/EED_{before})^{\xi} - 1] * GDP_{initial} \qquad (2)$$

where ΔGDP = change in GDP for the Greater Sydney Region ($577b was used as the initial GDP figure for 2023, pre-transport improvements, based on data provided by the National Institute of Economic and Industry Research); ξ = the elasticity of productivity with respect to effective economic density (a value of 1.0021 was used, based on Hensher et al. 2012); and, EED = effective economic density (a measure of the accessibility of each zone to employment in other zones, weighted by the generalised cost of movement between that zone and each other zone).

Applying this formula for the PLR implies agglomeration economies (benefits) of $7.1m in 2023, increasing to $35.6m in 2033, with an estimated PV of $282m (Table 10.4). Conversely, the M4 is predicted to generate agglomeration costs, of $12.1m in 2023 increasing to costs of $14.1m in 2033, with a negative PV of $147m. The doubling of bus service frequencies for BSA 1 is an intermediate result, producing estimated agglomeration benefits of $10.0m in 2033, for a PV of $81m (Table 10.4). The BSA2 is predicted to generate agglomeration costs of $4.9m in 2023 increasing to $18.9m in 2033, with a negative PV of $154m.

In terms of agglomeration benefits, it is noteworthy that the Queensland Government's Business Case evaluation of the Gold Coast Light Rail Stage 3 estimates wider economic benefits of $539m (of which agglomeration benefits are usually the largest component), with an additional $599m for urban regeneration benefits from that 6.7 km LR route extension project, both being larger individually than the estimated capital cost of that Gold Coast project (Infrastructure Australia 2019). This comparison makes the estimate in the current paper, which includes only agglomeration benefits, conservative.

Figure 10.6: Predicted changes in residential location associated with the four projects for 2033 (% changes)

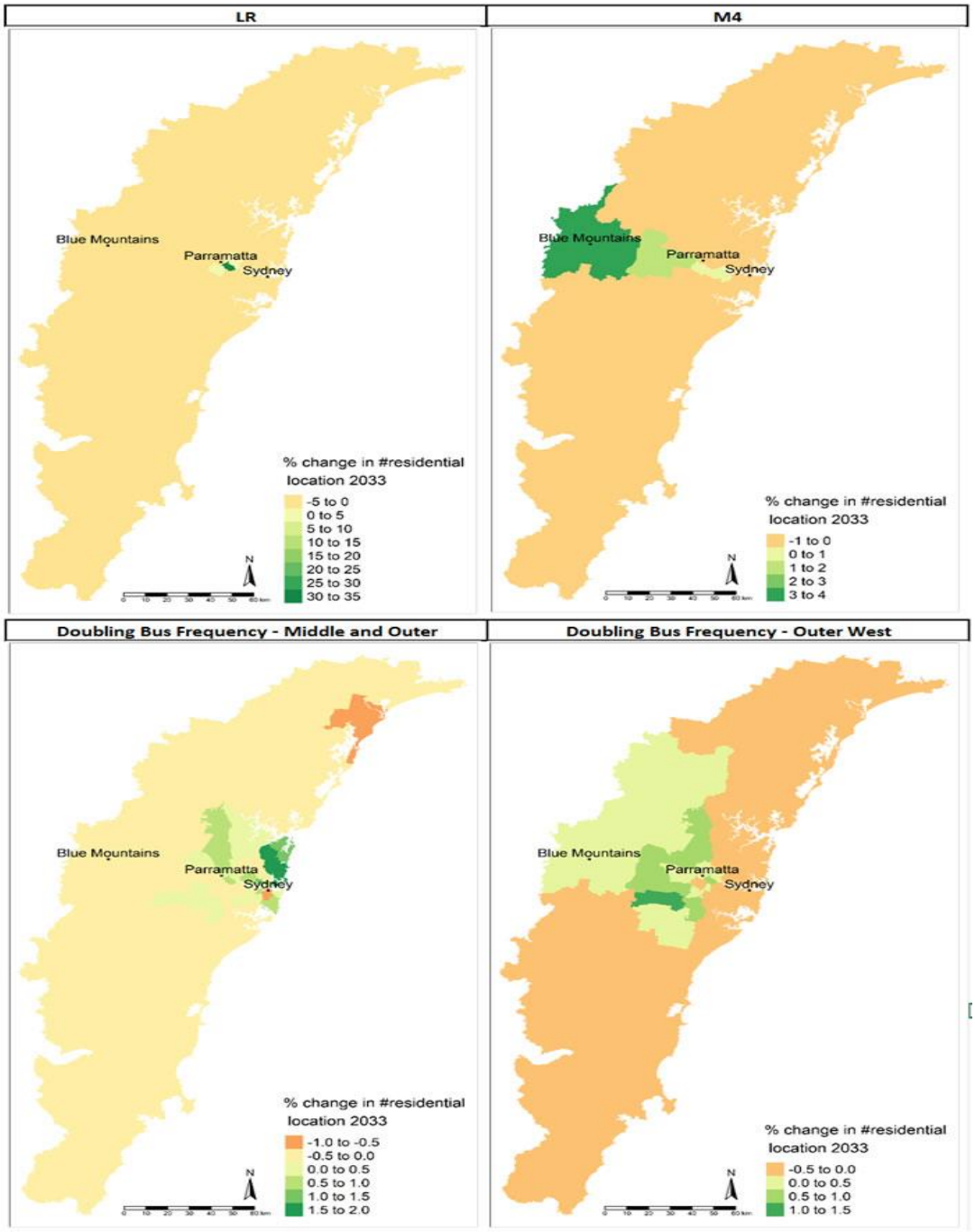


Figure 10.7: Predicted changes in job locations associated with the four projects for 2033 (% changes)

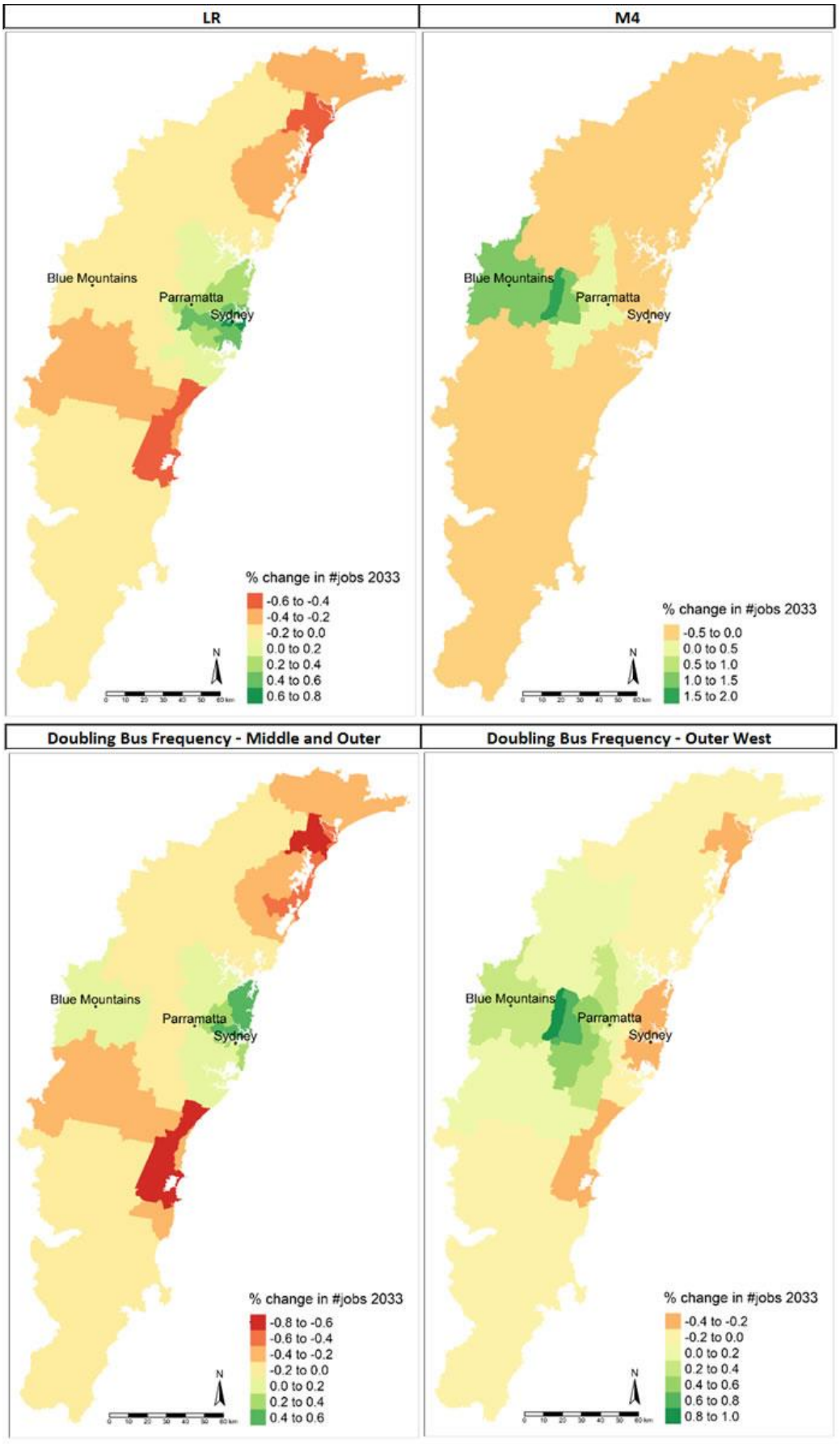
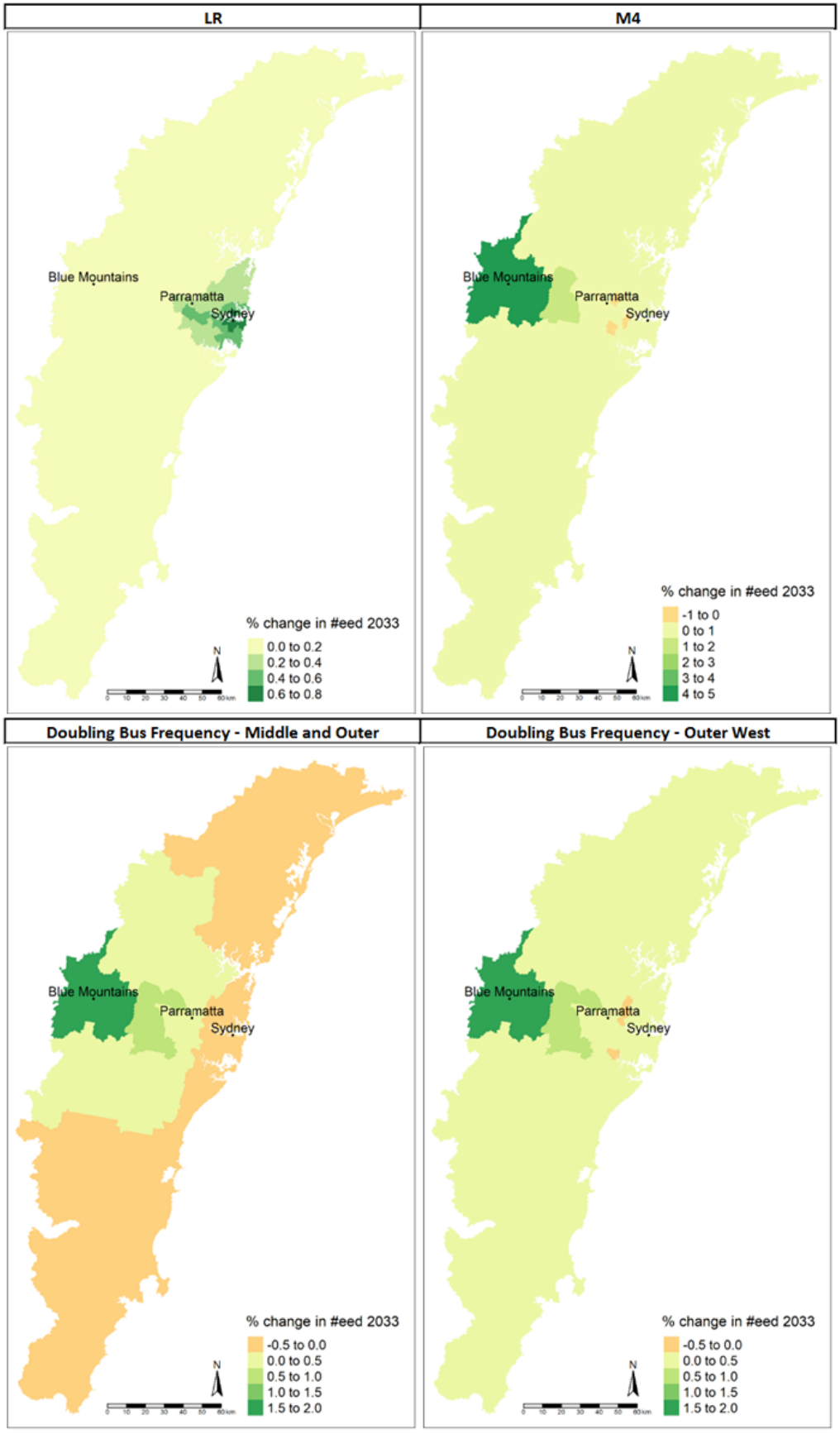


Figure 10.8: Predicted changes in effective economic density (EED) associated with the four projects for 2033 (% changes)



Walking is recognised as being beneficial for health, with Australia's transport appraisal guidelines enabling attribution of a monetary value to **walking** associated with some transport initiatives (TIAC 2016). We concluded in Section 6 that a bus trip is worth ~$3.25 in terms of incidental health benefits for adults. This value is in line with the value for walking set out in the Australian transport evaluation guidelines for active travel (TIAC 2016), taking account of bus walk times shown in Section 6. Assuming that:

- the same unit values apply to light rail use as to bus, which requires similar overall walk lengths as between LR and a bus per trip; and
- half the increased use of PT associated with any of the three projects being assessed herein is by adults,

the walking benefits of the PLR are estimated to be worth around $48m annually in 2033, with a PV of $419m (Table 10. 4). Conversely, the M4 upgrade is predicted to reduce PT use, which implies less incidental walking and consequential higher health costs (PV of cost is $31m; Table 10.4). The largest walking benefits are predicted for BSA1, which leads to the biggest increase in PT trips of the four options considered herein (50.7m extra PT trips in 2033). This converts to a benefit value of $514m in PV terms. The smaller, more focussed increase in bus service frequencies associated with BSA2, is estimated to deliver an additional 20.9m walking trips to/from PT in 2033 (PV of $212m).

MetroScan estimates accident rates and associated **accident costs**, including fatality, personal injury and property damage accidents (Appendix A). Using TfNSW unit values, accident costs were predicted to be $44.5m lower in 2023 with the PLR than without it (PV $379m; Table 10.4). The M4 upgrade, however, is predicted to increase accident costs by $4.7m in 2033, associated with the increased road use and lower PT use, with a PV of $48m cost. Doubling bus frequency as per BSA1 is predicted to reduce accident costs by $52.8m in 2033. In PV terms, the stream of accident cost savings in this case is valued at a substantial $462m, the largest of the four projects considered herein. This is halved in BSA2 (Table 10.4).

Operating costs for the PLR were not identifiable from any of the reports that were scanned for this case study. However, a review of reported operating costs for several other Australian Light Rail projects, planned or in place, suggests that PLR operating costs might be expected to be between $3m to $6m per track kilometre per year, or between $36-72m p.a. for the route. The low-end costs are in prices from studies of around 6-7 years ago and for service extensions, suggesting that a more realistic range is perhaps $50-$72m. We assume $60m p.a. keeping it constant in real terms, on the assumption that productivity gains will be sought by government to offset provider cost increases.

This produces estimated operating costs equivalent to 25.7% of the PLR capital cost in PV terms (or ~20% of combined capital plus operating costs), which is similar to the share for the Gold Coast LR extension (Infrastructure Australia 2019) and to the proportion estimated by Hensher et al. (2019) in an evaluation of a hypothetical LR to Sydney's Northern Beaches. This may be a little favourable to the PLR, however, Douglas and Cockburn (2019) presenting data showing that the Canberra operating/capital costs ratio was 1:3, which would take the PLR operating costs to $800m in PV terms, or around $180m more than assumed herein.

Operating cost estimates for the M4 upgrade were derived in a similar manner, by examining costs for some other major road projects, particularly the relative proportions of operating costs to capital costs. Infrastructure Australia project evaluation sources were relied on for this information, which uses evaluations undertaken by the relevant responsible authority[19]. The projects used for this purpose were three NSW road projects (Newcastle Inner City Bypass, Western Harbour Tunnel/Warringah Freeway upgrade and M12 Motorway) plus Melbourne's proposed NE Link. Based on the range of the operating to capital cost ratios for these projects, it was assumed that operating costs for the M4 would be 5% of capital costs in discounted terms. Capital costs have been assumed to be $2400 in both discounted and undiscounted terms (2019 prices), because the authors have no knowledge of the construction time. Table 10.4 suggests discounted operating costs of $120m.

Costs for the doubling of bus frequencies have been based partly on research by the NSW Independent Pricing and Regulatory Tribunal (IPART 2014). IPART estimated that the net costs of bus service provision by Sydney's private bus operators was $611m in 2013 prices, based on the costs of efficient operators and excluding school service costs (which are not relevant to the doubling of frequency considered herein). These costs were increased by 3% p.a., to put them in approximate 2019 prices, which amounted to $730m. Doubling service frequencies will not double these costs, since not all privately operated routes are included, some additional kilometres will be achievable from the base fleet and some costs will be fixed. Based on the authors' knowledge of route bus service delivery costs in Sydney, Melbourne and elsewhere, It has been assumed that doubling service frequencies over the broader network of BSA1 will add $500m p.a. to service costs, once fully rolled out (from 2033), building to this over the preceding decade. The smaller bus service upgrading option (BSA2) has been assumed to cost $325m when fully in place, also building to this from 2023. In PV terms, the cost of BSA1 is an estimated $4632m and that for BSA2 is $3010m (in 2019 prices and 2021 PVs) (Table 10.4).

[19] Project Evaluations | Infrastructure Australia.

10.7 Changing travel patterns and implications for social exclusion risks

One of the purposes of this paper is to explore possible impacts of major transport initiatives on reducing risks that people will be socially excluded because of poor mobility opportunities. Sydney's different zones have been categorised in terms of relatively more/less risk of mobility-related exclusion, using widely available indicators (Section 10.3 above). Changes in trip making by people living in the two most at-risk zones is used as the indicator of the prospective reduction in exclusion risk, providing a basis for valuing that risk reduction. Changes in the total number of trips in 2023 and 2033 were thus assessed for all zones categorised as being at *most risk* or at *moderate risk* of residents experiencing mobility-related social exclusion.

Table 10.1 indicated that MetroScan predicts the PLR will lead to an increase in total trips of 7.1 m in 2033, which suggests substantial potential for social inclusion value. The largest changes in predicted travel patterns for this project, particularly PT trips and total trips, are unsurprisingly in the vicinity of the route. For example, Parramatta-Inner is predicted to gain 130,000 train trips a day in 2033 and Holyroyd an additional 40,000. Parramatta-Inner is in the zones that were categorised in Figure 10.5 as being at moderate risk of mobility-related social exclusion and Holyroyd is in the zones categorised as at most risk. This is where the greatest reduction in car trips is also expected (car driver plus car passenger). Looking at trips overall, while trips increase in areas close to the PLR, they decrease slightly elsewhere. Thus, while there is likely to be a reduction in risks of mobility-related social exclusion in zones close to the LR, risks may increase a little in some other areas.

Overall, in 2033, the PLR was predicted to lead to 2.7m fewer annual trips by residents from zones categorised as being *at most* risk but 17.8m additional trips were predicted to be made by residents living in zones categorised as being at *moderate risk*. Adding these predicted changes in trip making together suggests a net additional 15m trips in 2033 which are likely to be associated with reduction of risk of mobility-related social exclusion.

The values of additional trips for those at risk of mobility-related social exclusion, as most recently estimated by Stanley et al. (2021a) were updated to 2019 prices and applied to these reduced/increased trip numbers respectively. The resulting additional trip value was $22.75. No social inclusion value was put on increased/reduced trips from zones categorised as being at lowest risk or low risk. For the PLR, the resulting social inclusion benefits were valued at $344m in 2033.

However, including social inclusion benefits creates a risk of double counting benefits from increased trips, since generated traffic benefits (which will be part of the inclusion benefit) already form part of the user benefit estimate. To avoid this risk, all generated traffic benefits were deducted from the social inclusion benefit measure ($8.8m in 2033).[20] In present value terms, the social inclusion benefit value of the PLR, after deducting generated traffic benefits, was estimated to be a hugely significant $2752m at 7% discount rate (Table 10.4), which exceeds the project capital cost.

Stanley et al. (2011a, b, 2021b) showed that the value of additional trips to those at risk of mobility-related social exclusion increases in inverse proportion to household income. The benefit estimates outlined above, do not include this income adjustment, since such weighted assessment has not been used for other benefit/cost items. If allowance had been made for varying household income levels between zones, the social inclusion benefit figure for PLR would have been increased by one-fifth, adding an extra ~$500 million to the project's value.

The M4 is also predicted to generate some social inclusion benefits (benefits relate to trips rather than modes), with a net additional 1.3m trips in 2033 from the two categories of zones where mobility-related social exclusion risk is likely to be relatively high, particularly through added trip making supported in western areas, such as the Blue Mountains, Penrith and Blacktown and also around Parramatta and Holyroyd. These numbers are much smaller than the additional trip making predicted from more at-risk areas attributable to the PLR (e.g., a net additional 15.1m trips for PLR in 2033). PLR is thus assessed as being much more important in terms of potential social inclusion benefits, its exclusion benefits being valued at $2.75b in PV terms, compared to a PV of $353m for the M4 (Table 10.4).

Doubling bus frequency as in BSA1 was predicted to lead to a larger increase in PT use than building the Parramatta LR, so there is potential for significant social inclusion benefits from this bus initiative. However, the widespread nature of this improvement suggests that it will benefit citizens across most parts of the city, irrespective of whether they are at risk of mobility-related social exclusion or not. MetroScan modelling suggests that there will be an additional 3.3m trips from zones categorised as being at most or at moderate risk of mobility-related social exclusion in 2033, with numbers split broadly equally between the two categories of risk. These numbers are considerably smaller than for the PLR in 2033 (at 15 million additional trips), the PLR being more focussed on zones where exclusion risk is likely to be higher. As a result, the

[20] Strictly speaking, generated traffic benefits to trips from zones with least or low exclusion risk could be retained since there were no inclusion benefits counted for these zones. However, the Figure 11.s involved are sufficiently small to ignore for the purpose of the current study.

social inclusion benefit expected from BSA1, while very significant at $645m in PV terms, is considerably less than has been estimated for the LR ($2.75b) but it is substantially larger than the inclusion benefits estimated for the M4 upgrade ($353m).

Aiming the doubling of bus service frequencies more clearly at areas of higher exclusion risk can increase exclusion benefits. BSA2 was developed for this purpose. It increases the number of trips from zones categorised as being at most risk or at moderate risk by 10 million in 2033, three times the number estimated for BSA1, even though BSA2 is only about two-thirds the overall scale of BSA1 (in terms of annual cost). PLR was estimated to generate 15m trips in 2033 from such zones. The PV of social inclusion benefits for BSA2 was estimated at a substantial $1.92b (Table 10.4), three times the value for BSA1.

10.8 Summing up the evaluation

Table 10. 4 sets out a summary of the economic assessments undertaken on the four major Sydney transport initiatives. All four projects show good economic returns overall. PLR has the lowest BCR, at an acceptable ~1.4, with the two bus projects both having stronger BCRs, each around 1.9. The M4 upgrade achieves a BCR of a higher 2.7. The differences between the base and policy driven environmental assessments make little difference to the BCR of any of the projects.

User benefits are the main reason for the good economic outcome of the M4 upgrade and for the doubling of middle/outer urban bus frequencies (BSA1). In the case of PLR, the good economic result is highly dependent on social inclusion benefits, which is also a key component of the benefits for BSA2, the bus upgrade aimed at areas assessed as being at higher exclusion risk. Freight benefits are important in all three evaluations, showing the value of having an integrated model like MetroScan on which to base the analysis and assessment.

Increased economic density, with associated agglomeration benefits, are handy positive contributions from two of the PT projects, the PLR and BSA1, but are a negative for the M4 upgrade and BSA2 because of the encouragement to lower density development in outer areas that the latter two projects provide. This shows the value of having an analytical capability that can predict changes in residential and job locations as a function of transport system changes. Reduced accident costs and the health benefits from increased incidental walking are positives for the three PT projects but small negatives for the M4 upgrade.

Net greenhouse gas emission and air pollution benefits/costs are shown on two bases, as described in Section 10.5: a base case and a policy driven alternative. The numbers shown in brackets in Table 10.4, for GHG and air pollution, are for the policy driven alternative. The three public transport projects are predicted to deliver small benefits from reduced GHG emissions but the M4 upgrade is predicted to lead to an increase in GHG emissions and associated costs.

Air pollution costs associated with the M4 project are substantial and much larger than its GHG emissions costs. The policy driven alternative reduces estimated air pollution costs from the M4 project by over $60m. Doubling bus frequency in BSA1 is predicted to increase air pollution costs by $151m in the base case, where bus fuel technology is assumed unchanged (reliance on diesel), but the policy driven alternative substantially reduces this effect (by about $40m). The smaller scale of BSA2 halves the air pollution impacts of BSA1. Increased freight traffic in all three cases adds significantly to GHG and air pollution costs.

Table 10.4 Overall transport benefit/cost estimates ($m; 2019 prices; 2021 PVs; 7% real discount rate)

Benefit/Cost item	Parramatta LR	M4	Bus service additions (1)	Bus service additions (2)
BENEFITS				
PT benefits	2416	144	5557	2341
Car user benefits	-3772	5523	-2250	-598
Freight benefits	1038	1332	2455	1231
Agglomeration benefits	282	-147	81	-154
Air pollution: local	-2 (-8)*	-178 (-114)*	-151 (-112)*	-75 (-55)
GHG emissions	30 (15)*	-18 (-12)*	24 (12)*	12 (6)
Walking benefits	419	-31	515	212
Accidents	379	-48	462	231
Social inclusion benefit	2752	353	628	1916
State fare revenue	1028	-120	1923	786
Federal excise revenue	-182	5	-238	-119
Toll revenue	-6	1	-0.1	2
Total benefits	**4382 (4361)***	**6816 (6886)***	**9005 (9032)***	**5785 (5799)**
COSTS				
Operating costs	663	120		
Capital cost	2400	2400		
Estimated total costs	**3063**	**2520**	**4632**	**3010**
NET BENEFITS	**1319 (1298)***	**4296 (4366)***	**4373 (4400)***	**2775 (2789)**
BENEFIT/COST RATIO	**1.43 (1.42)***	**2.73 (2.70)***	**1.92 (1.95)***	**1.92 (1.93)**

Note: * The figures in brackets are for the policy driven environmental alternatives for GHG emissions and air pollution.

The MetroScan estimate of changes in fare revenues associated with the PLR (Table 10.4) suggests that increased fare revenues can cover all the operating costs of the PLR, which are low relative to the project's capital cost, and about a third of total project costs. A slightly higher overall financial (fare) cost recovery rate (of about 38%) is estimated for the comprehensive doubling bus service frequencies (BSA1), with its predicted solid growth in patronage. The fare box cost recovery rate for the more focussed BSA2 is lower, at 24%, which is not surprising since this project is primarily aimed at social inclusion.

Social inclusion benefits are crucial for the economic worth of the PLR project and contribute significantly to the value of doubling route bus service frequencies in the outer west (BSA2). There is also a benefit of some importance here for the M4 upgrade, given the increased trip making it encourages from western zones at higher exclusion risk. Had allowance been made for different zonal household income levels in estimating inclusion benefits, the value of the PLR would have increased by ~$500m. This same sensitivity test was not undertaken for the M4 or for either of the two doublings of bus frequencies but increased benefit estimates are likely, particularly for BSA2 which is focussed on zones with higher exclusion risks.

Terrill (2021a) identifies how the larger Australian transport infrastructure projects tend to over-run their initial cost estimates more than lower cost projects, with projects costing a billion dollars or more exceeding their initial cost estimates nearly half the time and, when they do exceed these cost estimates, it is typically by more than $600m (Terrill 2021b). There is thus fair chance that either or both of the PLR and M4 projects might end up costing $3b, or more, rather than $2.4b. This would lower the BCR of the M4 from ~2.7 to ~2.2 (or less) also and lower the BCR of PLR from ~1.4 to ~1.25 (or less). Doubling bus frequencies are not an infrastructure initiative and should not be subject to such price pressures, making their estimated BCRs more resilient.

10.9 UK case study

Leeds University's Institute for Transport Studies has undertaken an informative study of connections between bus accessibility (as measured by travel times) and the UK's Index of Multiple Deprivation (IMD), as a measure of a number of social outcomes (Johnson 2016). We provide a brief overview of that study here because it is the only study we identified that tries to grapple with similar matters to the current report in a comprehensive way.

The IMD is a 38-item measure across seven domains of deprivation: income; employment; health and disability; education skills and training; barriers to housing and services; living environment deprivation; and, crime. Access measures were removed from the IMD component indicators, so that the relationship between accessibility and deprivation could be analysed. Indicators of journey time to employment centres, GPs, hospitals and town centres, in areas where bus services are the dominant form of public transport, were used as accessibility indicators, which meant restricting the analysis to urban centres where bus was the dominant PT mode[21]. This meant excluding cities like London and Manchester.

The models developed in Johnson (2016) produce elasticity estimates that show the expected relative change in five outcome indicators for a given change in bus accessibility (travel time improvement). Elasticity estimates were produced for each of the IMD deciles. For a 10% improvement in bus accessibility, the following average changes in the five outcome indicators were estimated:

- employment deprivation = 2.7% fewer unemployed;
- income deprivation = 2.9% fewer individuals from benefit claiming households;
- post-16 education = 0.7% more staying on to post-16 education;
- entry to higher education = 0.1% more entrants to higher education; and
- adult skills = 1.2% fewer unskilled adults.

Across each of the five outcome areas, impacts tended to be somewhat stronger across the more deprived deciles of the IMD. Johnson (2016) translates these relative changes to lower numbers unemployed and lower numbers claiming benefits, across the IMD quintiles. These numbers are not so relevant to Melbourne, because they come off a larger urban base in the UK. However, for information, Johnson (2016) predicts almost 10,000 fewer unemployed, 22,000 fewer benefit claimants and 7300 fewer adults with no skills in the lowest IMD decile, reducing to 570 fewer unemployed, 1080 fewer benefit claimants and 1250 fewer unskilled adults in the highest decile. Johnson (2016) also reports higher life expectancy following the 10% improvement in bus service accessibility (travel times), although the detail of this finding is not provided in the report.

10.10 Conclusions from case studies

This section has demonstrated the application of a land use transport planning modelling system (MetroScan) for the assessment of four major transport initiatives in Sydney (a new Light Rail line, a major motorway upgrade and two alternative doublings of bus service frequencies), for the purpose of enabling a comparative assessment of

21 PT accessibility data was not mode specific, so towns and cities where bus was the dominant mode were chosen to enable bus-specific conclusions to be drawn.

these substantially different transport alternatives. All projects are shown to produce positive net benefits, user benefits the main contributor to this result for the motorway and both bus upgrade projects, with social inclusion benefits the main justification for the Light Rail and a key benefit component of the bus upgrade project that is focussed on areas at relatively greater risk of mobility-related exclusion (BSA2). As argued in Section 9.5 above, we believe that these exclusion benefits will include an unquantified component of the external benefits attributable to reduced social exclusion. The dynamic modelling approach used in the Sydney case studies has also shown the importance of benefits to freight movement for each of the three initiatives.

Agglomeration benefits are one focus of many transport appraisals. This analysis suggests that major public transport upgrades that encourage inner/middle urban growth may deliver useful agglomeration benefits but that major road upgrades and PT upgrades that benefit outer areas run the risk of reducing effective economic density, with adverse impacts on agglomeration. The dynamic nature of the transport and land use interactions reflected through MetroScan have been important in illustrating these quite different agglomeration tendencies. The potentially negative agglomeration impact of a major road upgrading project is a cautionary finding in an Australian urban setting.

The assessments reported herein show some small benefits from reduced GHG emissions from the three public transport projects but increases for the M4. Increased air pollution is predicted for all four projects (albeit minimal for PLR), largely because of the impact of additional freight movement. Even with GHG emissions, however, it is important to note that, in 2033, in each of the four assessments the total CO_2 (project value) emissions for the base case environmental assumptions were still estimated to be at least 20% *higher* than the 2023 base level of emissions. This underlines that there is much to be done if Australia is to make serious inroads into reducing its high level of greenhouse gas emissions, with motor vehicles, including trucks, needing to be an important focus.

The alternative estimates of future GHG emissions assumed herein, which embed a 5% p.a. policy-driven reduction in vehicular GHG emissions and air pollutant levels, is indicative of the scale of change needed in this regard. This requires initiatives such as regulatory-driven improvements in emissions performance at the motor vehicle level (e.g., fuel economy standards, tighter standards for PM emissions from diesel engines), carbon-pricing and other incentives to encourage a faster shift to electric vehicles and accelerating a switch away from cars to public transport and active travel. In this regard, it is notable that, by 2030, the NSW State Government wants all route bus services replaced with electric buses, so tailpipe CO_2 emissions will be zero and air emissions substantially reduced. The Victorian Government, in similar vein, has announced that 36 new electric buses will be added through Kinetic's Metropolitan Bus Franchise by 2025 and that all new route buses from 2025 will be zero emission (from tailpipe). This kind of State Government policy leadership needs to be replicated and broadened.

The solid economic performance expected from both variants of doubling bus frequencies analysed in this section is notable. Rarely is such an option included as part of a city's transport strategy, often because governments and their treasuries dislike committing to ongoing service delivery costs: once-off outlays on big capital works seem to have greater political appeal. This assessment has shown that widespread upgrading of bus services can deliver good economic returns, suggesting they should be one option considered within integrated urban transport strategies for Australian cities, and that targeted improvements in frequencies can support social inclusion and deliver solid project economic returns.

A key finding from these Sydney case study examples is the importance of social inclusion benefits for targeted PT projects. Without those benefits the PLR would look like a white elephant. With their inclusion, it measures up well. These benefits were not adjusted for household income but, if such adjustment had been made, the PLR would have had an even better evaluation outcome, suggesting that taking account of who gains and loses is important in project appraisal. Bus frequency increases on services in areas of disadvantage have also been shown to support project viability.

Surprisingly, social inclusion benefits are currently not counted in Australian transport cost-benefit analyses, even though providing travel opportunities for transport disadvantaged people has long been a primary reason for provision of PT services. The estimation of social inclusion benefits in the current study shows that they are potentially very significant. Social inclusion benefits should form part of the assessment of all major transport initiatives, and particularly for public and active travel costs.

The section has also referenced some relevant UK research. Johnson (2016) shows that increasing the availability of bus services in the UK can be expected to contribute to reducing disadvantage (supporting greater social inclusion). Importantly, that UK research also illustrates that quantification of the value of social exclusion external benefits attributable to bus remains at a very early stage of development.

11. Conclusions

Improved bus services, particularly in outer/middle parts of Australian cities and in regional areas, is one a way to reduce risks that people will be socially excluded because of poor mobility opportunities. Improved bus services can both increase the likelihood of social inclusion of individuals and also reduce the costs that society incurs when people are socially excluded. These wider societal costs include costs associated with poor physical and/or mental health, increased crime and reduced economic productivity. This report focusses mainly on these broader societal costs, which we call the external costs of social exclusion. These external costs are sometimes recognised but are not quantified when major transport (bus) initiatives are being evaluated.

The costs of social exclusion to the at risk-person can include (for example) higher medical costs and foregone income. Relevant benefit measurement work usually focusses on such quantifiable elements at the individual level. However, this paper shows that, when costs are measured in terms of the value of changes in individual subjective wellbeing, they are typically larger than when measured as changes in directly applicable costs, such as health costs or income changes.

The paper illustrates this for a setting in which someone is moved from unemployment to full-time employment. The benefit of this change in employment status is considerably higher when quantified as the monetary value of the increase in subjective wellbeing than it is when measured by the change in income received by the person plus government savings in welfare payments. Bus projects, and other initiatives, that enable someone to shift from unemployment to full-time employment would thus deliver higher benefits when evaluated in terms of increased subjective wellbeing. This valuation method is consistent with one of the fundamental value judgements that underpin cost-benefit analysis: that individual preferences should be normative for social choice.

A change in employment status, from unemployed to full-time employed, will obviously benefit the job winner. If employment density increases, it may also generate agglomeration economies, which are a positive external (societal) benefit. Section 10 of this report has shown that widespread doubling of bus service levels can create such agglomeration economies (benefits) but may lead to agglomeration costs if those service improvements are concentrated in low density outer areas. In the latter case, improvements may encourage faster outer urban growth, which can lead to lower overall effective economic density, with resulting agglomeration costs. This does not mean that bus services should not be improved in outer urban areas, since social inclusion benefits will typically be highest in such settings. It means that risks of agglomeration losses should be recognised when such bus service improvements are undertaken, suggesting integrating improved bus services with urban development initiatives that will directly increase outer urban densities, in line with the philosophy of 20-minute neighbourhoods. This is about integrated land use transport planning for complete communities, not isolated initiatives.

The most readily quantifiable external exclusion benefit identified in this report is associated with the physical health benefits of walking, linked to bus use. The physical health benefits of walking comprise morbidity and mortality benefits plus savings in health system costs. The value of these various benefit components has been quantified in TIAC (2016) Guidelines. Analysis in Section 6 of this report confirms the broad scale of the health system (externality) component of those benefits. The report then uses the TIAC cost benefit estimates plus Melbourne data on walking by bus users to infer that an adult bus trip is worth around $3.25 in terms of 'walking benefits', which are comprised of health benefits to the walker (morbidity and mortality benefits) plus the wider societal benefit of health system cost savings. The overall benefit is split about 65%/35% between the walker benefit and the health system components, the latter being the externality. This suggests that Melbourne's route bus services are worth around $200 million annually in terms of adult walking/physical health benefits.

The research undertaken for this project also sought evidence about possible connections between improved mobility opportunities and better mental health and a lower crime rate. A few sources noted some general expectations about such outcomes but no quantitative evidence to support valuation of such influences was identified. The most likely pathway for such quantification we expect will be via improved mobility opportunities improving social capital (social connectedness), since there is an evidence base supporting a link from improved social capital/connectedness to some aspects of improved mental health and reduced crime. However, research in this area (linking improved mobility to improved mental health and reduced crime) is scarcely at the starting gate today. Our own research on connections between mobility, social capital and social exclusion is one potentially useful starting point.

The report includes new analysis on the contribution of (spatial) neighbourhood disadvantage to an individual's risk of social exclusion, finding that this is a significant but small contributing factor, alongside those individual socio-economic characteristics identified in our prior research. The value of trip making, as it contributes to reducing exclusion risk, was then re-estimated, taking account of the neighbourhood disadvantage effect, finding that an

additional (bus) trip is estimated to be worth around $22.75 in 2019 prices. The value is higher for those at greater risk of mobility-related exclusion and lower for those at low risk. It is also higher for those with lower household incomes and lower for those with higher household incomes. This value of additional trips is about 3 times the value that would be attributed to additional trips by the traditional rule-of-a-half in user benefit assessment.

The $22.75 trip value is, prima facie, not an externality: it is mainly a measure of the value of an additional trip to a person at risk of mobility-related social exclusion. The report suggests that this seemingly high trip value, by comparison with values from applying the rule-of-a-half, is likely to be attributable to two factors:

- taking an additional trip, for someone at risk of mobility-related social exclusion, is a non-marginal activity, since it will mean taking (for example) four trips a day instead of three, which is a substantial relative increase (one-third). For such a change, the value (consumer's surplus) that is expected from the activity associated with that additional trip should be included as part of the trip value that has been enabled by the transport initiative under consideration – this activity value would not have been created otherwise. The rule-of-a-half, by comparison, refers to marginal (small) changes across large numbers of trips/trip makers (e.g., a saving of one minute on a car trip). The $22.75 value is, however, close to what the rule-of-a-half might indicate is the value for a new trip by the most expensive but most widely available alternative mode for most urban trips = a taxi, a theoretical choice only for many who are socially excluded;
- we believe that the $22.75 value is picking up part of the external costs of social exclusion, which are a consequence of an aggregation of the personal costs of exclusion across large numbers of people. When large numbers are excluded, societal costs also rise for all. When numbers who are excluded fall, so will the wider societal costs. The way that the model that estimates risk of social exclusion is specified may mean that it is picking up some (unknown) part of the wider societal costs of exclusion. We think this is highly likely and that using the $22.75 value of a trip is going some way to monetising exclusion externalities. Adding separate estimates of particular societal exclusion costs may then pose questions of possible double counting of benefits.

The report has taken the opportunity to compare the benefits and costs of doubling bus service frequencies across large parts of the Sydney bus network with building the Parramatta Light Rail and widening the M4. The assessment shows a strong benefit-cost result for both the doubled bus frequencies (benefit-cost ratios of ~1.9). When that frequency increase is very widely dispersed, bus user benefits are strong. When it is more focussed on areas of higher exclusion risk, inclusion benefits are strong, supporting user benefits. Freight benefits are important in both cases, an important finding that is often overlooked in transport policy and planning, showing the benefits of the integrated dynamic modelling framework used in the case studies (the MetroScan model). These results show the importance of strategic transport policy and planning looking not only at large infrastructure projects but also at opportunities provided by major increases in bus (PT) service levels, as distinct from small numbers of isolated service improvements. The case studies also highlight the urgency of regulatory interventions to drive lower GHG emissions and air pollution levels from Australian road transport.

An issue that requires further research is the extent to which the benefits of employment increases predicted to be associated with major transport initiatives, such as the Sydney case studies included in this report, should be monetised and counted as benefits in a cost-benefit analysis of those initiatives. The Sydney case studies have shown this could amount to a very sizeable benefit. However, potential employment losses associated with funding of the relevant transport initiatives would then need to be recognised and counted in benefit-cost assessment. Exploring this issue is beyond the scope of the current paper but should be considered in the Melbourne project being undertaken by NIEIR for BusVic.

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Appendix A: Parameter values used in Sydney case studies

	Commute		Non-commute		Business			
	Car	**PT**	**Car**	**PT**	**Car**	**PT**	**Freight**	**LCV**
VTTS per person ($/person hour)	17.72	17.72	17.72	17.72	57.48	57.48	31.05	25.41
Average vehicle occupancy	1.7		1.7		1.3		1	1
Value of travel time reliability (VoR) ($/person hour)**	30.12	Bus only	30.12	Bus only	97.72	97.72	52.79	52.79
Value of out-of-vehicle time ($/person hour)	26.58	26.58	26.58	26.58	57.48	57.48	N/A	N/A
CO_2 emissions (c/km)	2.66	15.61 bus; 0.8 rail; 32.69 light rail	2.66	15.61 bus; 0.8 rail; 32.69 light rail	2.66	15.61 bus; 0.8 rail; 32.69 light rail	3.67 rigid, 14.64 articulated	2.35
Air pollution (c/vkm)	3.37	37.9 bus; 4.99 rail; 41.42 light rail	3.37	37.9 bus; 4.99 rail; 41.42 light rail	3.37	37.9 bus; 4.99 rail; 41.42 light rail	16.5 rigid, 65.82 articulated	7.56
Air pollution (c/pkm)	2.39	1.89 bus, 0.04 train, 0.64 LR	2.39	1.89 bus, 0.04 train, 0.64 LR	2.39	1.89 bus, 0.04 train, 0.64 LR	N/A	N/A
Carbon dioxide equivalent (CO_2-e) $/tonne*	62.79							
Carbon monoxide (CO) $/tonne*	3.95							
Oxides of nitrogen (NOx) $/tonne*	2.503.55							
Particulate matter (PM10) $/tonne*	398,451.75							
Total hydrocarbons (THC) $/tonne*	1,254.41							
Fuel excise (proportion of fuel price)	0.416							

Note: * Source: TfNSW (2020).

Appendix B: MetroScan overview

One of the most important features of comprehensive land use and transport planning is an ability to identify candidate projects and policies that are adding value to the sustainable performance of transport networks and to the economy as a whole. There is a case to be made for having a capability to undertake, in a timely manner, a scan of a large number of potentially worthy projects and policies that can offer forecasts of passenger and freight demand, benefit–costs ratios and economy-wide outcomes. Such a framework would then be meaningful in the sense of offering outputs that are similar to those that are the focus of assessments that are typically spread over many months, if not years, on very few projects, which may exclude those which have the greatest merit. We named the system MetroScan Transport Infrastructure, or MetroScan for short. MetroScan, a strategic-level transport and land use planning application system allows for mapping of passenger and freight activity, as well as an endogenous treatment of the location of households and firms. In short, MetroScan is all-in-one forecasting and scanning system enabling us to conduct quick forecasting on the demand characteristics for cars, public transport, freight activities, and many other travel demand characteristics.

Figure B.1 shows how the macro generator works by taking inputs from existing transport models, such as the road and public transport network, and any OD matrices for the starting year to be used as a base, then uses the network travel times and distances by time of day. Characteristics of households, such as dwelling, household types, or car ownership, in synthetic data carry sociodemographic and behavioural elements into the system. The scheme also uses some defaults for values and distributions to fill in gaps when input data or models do not support such information (e.g., population growth rate or inflation rate). One of the central features of the macro generator is the adoption of macrozones. These macrozones can be predefined using the standard zone definition (e.g., from the Australian Bureau of Statistics), but can also be manually defined in the system. The macro generator can aggregate any OD skims to the macrozone layer. If executed outside the system, this would be a difficult task that can require months to correct. MetroScan has this process automated so changes to any OD skim matrices can be contemplated on the macrozone level when a proposed initiative is being processed. To provide further background, the macro generator applies a data manager to manage imported networks from different origins, such as TRANSCAD, VISUM, EMME, CUBE, and other systems. While preserving the accuracy for fast scanning, the macro generator largely reduces many detailed zones to a manageable number of macrozones, including the ones made by users. By doing so, initiatives under investigation can be assessed very fast in order to generate forecasting results from travel demand and economic impact. A trade-off exists between computation time and accuracy due to the detailed level of the macrozone. For example, in Sydney, there are over 3000 detailed zones in the transport network. In practice, we would apply 60 macrozones, which could satisfy both accuracies of forecasting and efficiency of the computation process. In reality, the forecasting results for major macro zones would also provide more meaningful and actionable insights for policymakers. Many strategic initiatives also start with higher levels of macrozones and request scanning results at the same level from travel demand to economic impact factors.

MetroScan was designed to apply synthetic households as units to gain numerous responses to alterations in the system driven by both broad and in-depth policy measures as presented in Figure B.2. MetroScan applies a large number of choice models on both the macro and micro level, including behavioural aspects, providing more behavioural realistic market responses robust in contrast to traditional model systems. MetroScan processes and delivers forecasts for different modes, travel purposes, and time-of-day choices for medium to long-term decisions up to 20 to 30 years (i.e., currently forecasting up to 2056). It also suggests long-term decisions or choices on vehicle types, fleet size, vehicle technology, residential and work locations, job and firm growth areas, dwelling types, and many others. Besides forecasting commuting, non-commuting trips, such as personal business and social purposes, and business trips, light commercial vehicle, and freight commodity models support business activity responses by location, volumes, and trips at macrozone levels.

Figure B.1: MetroScan framework

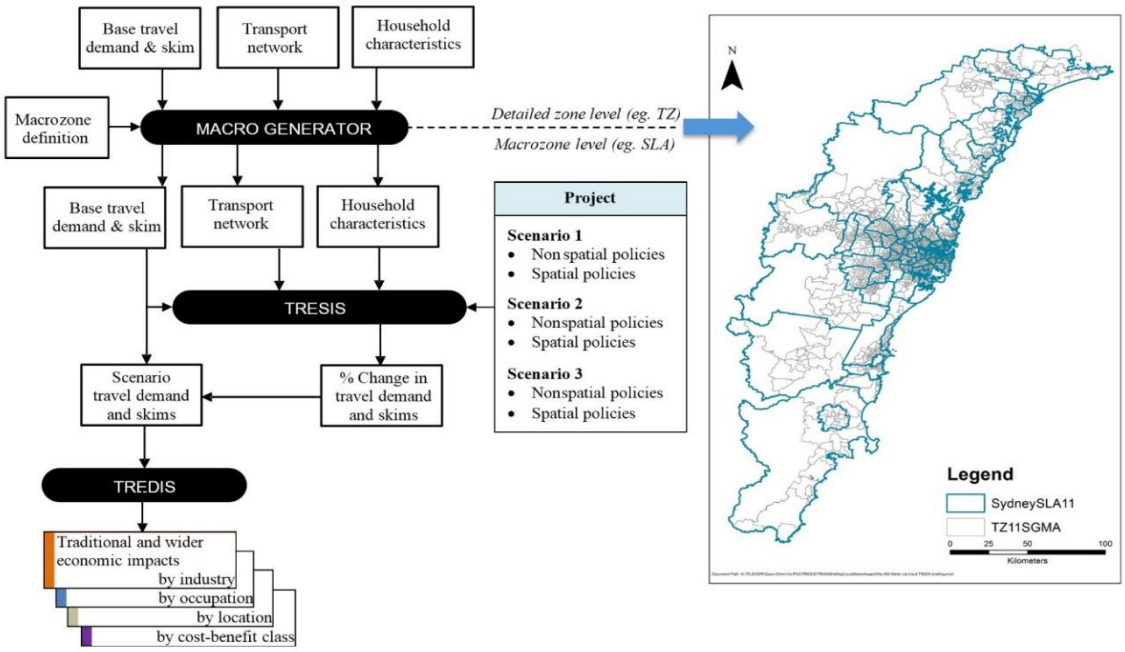
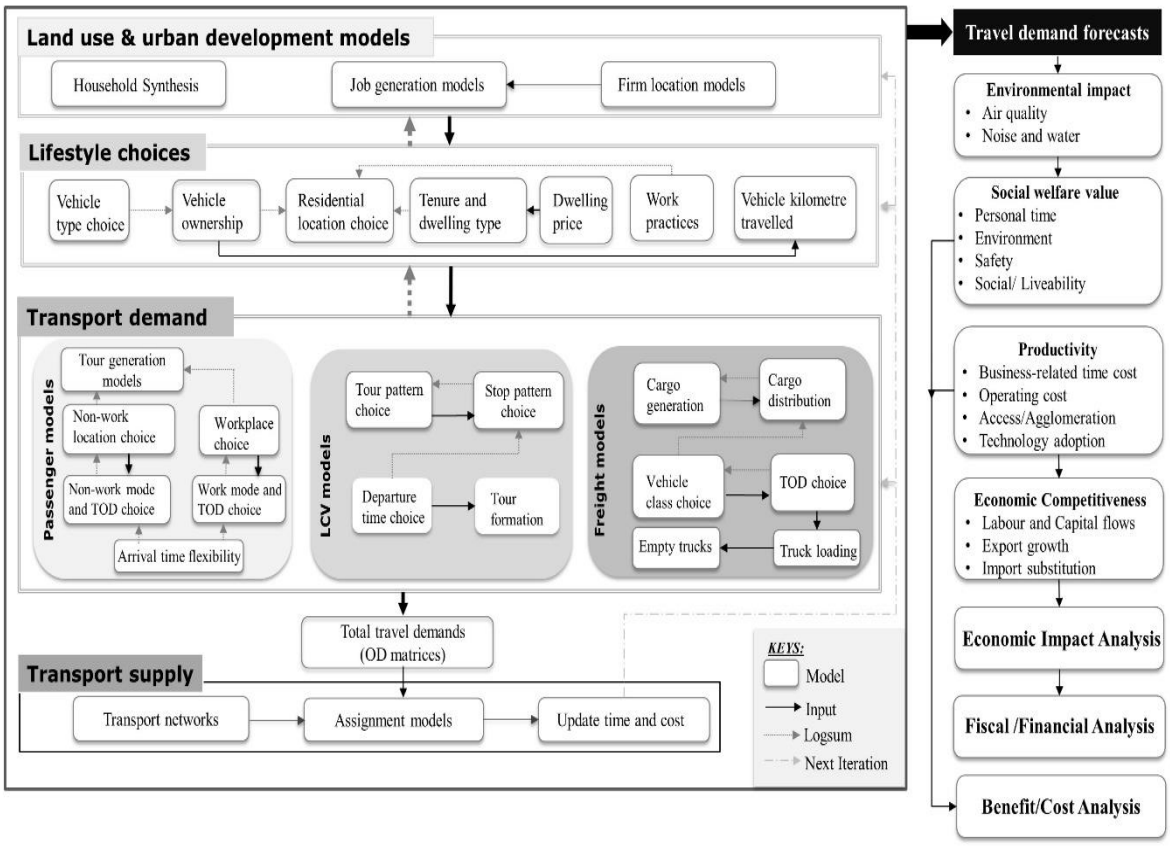


Figure B.2: The demand-side behavioural model system for passenger, light commercial and freight travel activity, and the benefit-cost analysis (BCA) and economic impact modules

(Source: Hensher et al. (2020))



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