Incorporating distributional impacts (equity) in the cost–benefit appraisal framework

November 2022

E Torshizian, Principal Economics, Auckland
A Byett, ECPC Limited, Taupō
E Isack, Principal Economics, Auckland
A Fehling, Principal Economics, Auckland
M Maralani, Principal Economics, Auckland

Waka Kotahi NZ Transport Agency research report 700
Contracted research organisation – Principal Economics

WAKA KOTAHI NZ TRANSPORT AGENCY
New Zealand Government

ISBN 978-1-99-004487-8 (electronic)
ISSN 2815-8377 (electronic)

Waka Kotahi NZ Transport Agency
Private Bag 6995, Wellington 6141, New Zealand
Telephone 64 4 894 5400; facsimile 64 4 894 6100
NZTAresearch@nzta.govt.nz
www.nzta.govt.nz

Torshizian, E., Byett, A., Isack, E., Fehling, A., & Maralani M. (2022). *Incorporating distributional impacts in the cost–benefit appraisal framework* (Waka Kotahi NZ Transport Agency research report 700).

Principal Economics was contracted by Waka Kotahi NZ Transport Agency in 2021 to carry out this research.

Keywords: equity effects, social cost–benefit analysis, transport distributional analysis

An important note for the reader

Acknowledgements

We would like to thank the members of the steering committee for this project: Ernest Albuquerque, Ian Melsom, Joshua Lee and Saeid Adli. We also appreciate comments received from Joanne Leung and Geoff Parr on earlier versions of this report.

We would like to thank the Auckland Forecasting Centre for providing the data. In particular, the advice provided by Sean Cavanagh, Nitin Mukkoth Valappil, Pete Moth and Jojo Valero is highly appreciated. We also appreciate the feedback received from Hamish Bunn, Auckland Transport.

We would also especially like to thank the peer reviewers Todd Litman, Executive Director of Victoria Transport Policy Institute, Canada, and Dr Adolf Stroombergen, Chief Economist of Infometrics Limited, Wellington.

Contents

Executive summary

Research has shown that transportation planning decisions often have large and diverse impacts on individual travellers and their communities. Therefore, it is important that transport planners, engineers and modellers identify and understand the distribution of these effects so the stakeholders they represent can take them into account.

Waka Kotahi currently uses an investment decision-making framework to determine the projects and programmes that will be undertaken within each activity class. Within this process, the economic business case must contain a cost–benefit analysis (CBA). A CBA is a method for assessing the economic efficiency of proposed policies or programmes through the systematic prediction and valuation (that is, monetisation) of all costs and benefits to all members of society. However, a CBA is an aggregate approach that, while it sums across a wide distribution of people, does not concern itself with where benefits and costs ultimately fall; nor does it concern itself, beyond what may be derived from peoples' willingness to pay (WTP), with any initial inequities.

In this report, we investigate the available methods for identifying and assessing the distributional impacts that could arise from transport interventions and identify a preferred method that could be used within the Waka Kotahi Monetised benefits and costs manual (MBCM). We then apply this method to a case study: the 2021 to 2031 segment of the longer-term Auckland Transport Alignment Project (ATAP).

We found that a distributional analysis provides further information for policy makers. The CBA and transport modelling typically integral to a transport CBA can be used to: (a) measure the distribution of effects and (b) quantify benefits and/or disbenefits of relevance to equity.

To arrive at our recommended approach for assessment of distributional impacts, we separated the equity issues that were primarily about measurement of equity within a CBA from issues such as those related to planning and decision-making. We also acknowledged the measurement and conceptual limitations of CBA and so sought measurements that could both contribute to a CBA and be used as quantitative inputs for further prioritisation tools, such as multi-criteria analysis (MCA). To develop a practical approach, we explored the practical implications of the methods presented in the literature and weighed up the pros and cons of the main methods, including the practicalities. This process led us to the recommended approach. The recommended approach is not seen as an end point but as a step forward that invites equity analysis into current CBAs and allows for progressive enhancements as new equity research emerges.

Transport equity discussions are focused on social justice. For the measurement of equity, it is necessary to identify the equity type and segment of society affected by an intervention, and identify and measure the range of outcomes. Amongst the theories of justice, further emphasis has recently been given to Sen's capability approach, which includes the ability of individuals to move freely from place to place to improve their 'capabilities' and achieve their 'functionings'.

We identify various forms or types of mitigation policies and measures to address adverse distributional impacts. Our literature review suggests a common approach amongst the studies that consider the CBA framework in their appraisals is to address the shortcomings of CBA using MCA. The use of MCA for considering the equity effects is consistent with Waka Kotahi MCA guidelines. In keeping with the available guidelines, we suggest the issues of distributive justice should be considered alongside the results of CBA and that different theories of distributive justice may be considered relevant. Accordingly, we suggest that the analysis of equity impacts should be provided for policy makers to decide.

We closely examined the practical implications of using alternative distributional weights within a CBA and developed a set of weighting options likely to be viable and criteria against which to judge each method. Based on our extensive literature review, we identified four methods for consideration of equity within a CBA.

We identified an MBCM consistent with method distributional analysis needs to provide equity estimates across various impacts and by considering different scenarios. The output measures from distributional analysis can also be used in a subsequent MCA, either instead of or to inform qualitative measures.

Our preferred method is to extend the current MBCM approach to distributional analysis, providing further scenario analysis of various impacts. This method provides a comprehensive approach using publicly available data and the current mobility-based approach of the Waka Kotahi MBCM.

We identified four scenarios for further investigation in distributional analysis:

- **Scenario 1 – baseline (MBCM):** This is the status quo method above, which we use as our baseline for comparisons with other scenarios.
- **Scenario 2 – extended scenario:** This scenario is to add measurements of benefits and disbenefits that are not included in scenario 1.
- **Scenario 3 – income adjustment:** This scenario adjusts scenario 2 for the decreasing marginal utility from income, providing a standardised and simplified version of a welfare-weighted method.
- **Scenario 4 – time effect:** This scenario accounts for long-term effects, including long-term health and environmental effects and even longer term intergenerational issues, using a lower discount rate (compared with scenario 2).

A standardised four-scenario approach allows a transparent and consistent appraisal of projects, and a more customised approach to CBA. It also allows a minimalist introduction of welfare weights into CBA.

Our analysis of the distributional impacts of the ATAP

We applied the preferred method to a case study (ATAP) and identified various distributional impacts. Table ES.1 summarises the findings from the assessment of distributional effects across household income groups. Table ES.1 does not show the magnitude of the differences in benefits to different income groups. Due to various measurement issues, we cannot provide further information on distributional impacts for air quality, security, severance labour market deepening and social cohesion outcomes. Our assessment excludes the full impact of the ATAP and the analyses provided should be used as a guideline only for our suggested method.

Table ES.1 Summary of the distributional analysis of the Auckland Transport Alignment Project 2021–2031

Social group	Household income groups				
	1) $1–$30,000	2) $30,000–$70,000	3) $70,000–$100,000	4) $100,000–150,000	5) $150,000 or more
User benefits	✓✓	✓✓	✓✓	✓✓✓	✓✓
Air quality	–	–	–	–	–
Accidents	✓✓	✓	✓✓	✓✓	✓✓✓
Security	–	–	–	–	–
Severance	–	–	–	–	–
Accessibility	✓✓	✓✓	✓✓	✓✓	✓✓✓
Labour market deepening	–	–	–	–	–
Social cohesion	-	-	-	-	-
Affordability	✓✓✓	✓✓	✓✓	✓	✓

Source: Principal Economics

Note: Ticks show the relative benefit to different income groups, ranging from less beneficial (✓) to more beneficial (✓✓✓).

Further alignment across government agencies' policy frameworks will be required.

The outcome of the distributional analysis provides information on various impacts. This needs to be complemented with wider investment and planning considerations, including any comprehensive policy framework that accounts for the overlapping impacts of transport, housing and taxing policies. This is important because house prices (and housing costs) act as an aggregator of the value of access to the amenities and facilities. With increases in the costs of housing, those with a lower affordability level move out, which leads to social exclusion. The National Policy Statement on Urban Development 2020 (NPS-UD) instructs councils to account for the availability of transport infrastructure in their assessment of housing and business development capacity. We suggest further investigation of the interactions between the current policy frameworks, particularly the Government Policy Statement on land transport, and the NPS-UD, in achieving a 'well-functioning' urban form.

The present study provides a useful approach for the assessment of distributional impacts, but further research is needed to improve the accuracy of the method and outputs of the distributional analysis.

Our research project provided a solution that generated useful information on certain distributional impacts. This provides analysts with an adaptable solution for identifying distributional impacts and reporting them together with the rest of the analysis to provide quantitative evidence for decision-makers. Further research will be required to identify and measure distributional effects of equity impacts not yet quantified. The list below notes the most important future topics that have been identified.

In the process of identification of the preferred method, we identified accessibility and enhanced-capability benefits (method D) as a comprehensive and useful method for considering equity effects. However, due to a range of missing information, we suggest not pursuing method D until that information becomes available. Future studies should provide further information on:

- The use of accessibility in the Waka Kotahi MBCM. Currently, the MBCM uses a mobility-based approach that is incompatible with the accessibility-based measurement required for method D. Further investigation is needed on the usefulness of replacing (or complementing) the mobility-based assessment with an accessibility-based method in MBCM.
- Available measures of accessibility and their relevance to policy targets, including resilience and wellbeing.
- The WTP of different socioeconomic groups for improved accessibility using the identified measures. We suggest that the current transport equity studies using method D do not account for WTP because they rely on Sen's capability approach (or a version of that). We also argue that an equitable transport policy needs to provide access to all groups, without taking demand into consideration. We suggest a more useful approach would be to account for demand and the importance of accessibility to different socioeconomic groups.

Our results provide quantitative information on various equity impacts and show an institutional approach that allows for different perspectives to be included within a CBA. It is not currently possible to measure all equity effects and, even with a fuller set of equity effects, the outputs of a CBA will always need to balance against other priorities. One issue highlighted is how to integrate the current mobility-based approach that sits within the standard transport CBA, which tends to favour investments that increase vehicle travel speeds and distances, with the emerging focus on capabilities and accessibility, which place more value on slower modes, demand management strategies and compact development. Additional research and data collection are needed to apply a more comprehensive transportation equity analysis that integrates these two perspectives.

Abstract

This study provides a methodology for assessing distributional effects of transport interventions using publicly available data and consistent with the current Waka Kotahi *Monetised benefits and costs manual*. Using a scenario analysis framework and various indicators, our identified method allows more measurement of equity effects to be included, as appropriate and as developed. The method also provides a crude assessment of the welfare effects and allows for higher weighting to be given to intergenerational equity. The outputs offer information on the benefits and disbenefits across impacts for different social groups. The results of applying this method to the Auckland Transport Alignment Project 2021–2031 provided information on distributional impacts across a range of outcomes, including user benefits, accidents, accessibility and affordability.

1 Introduction

1.1 Purpose

Waka Kotahi NZ Transport Agency engaged Principal Economics to research and develop an economically robust distribution and equity impact assessment framework that can be incorporated into the *Monetised Benefits and Costs Manual* (MBCM; Waka Kotahi, 2021b) for evaluating economic land transport activities in New Zealand.

The research report aims to contribute to Waka Kotahi by:

1. identifying and assessing the types of distributional and equity impacts that could arise as a result of transport interventions and initiatives
2. developing comprehensive methodologies and techniques so distributional and equity considerations can be assessed and quantified within a cost–benefit framework
3. providing guidance on the forms or types of mitigation policies and measures to address adverse distributional and equity impacts
4. applying the methods, techniques and mitigation polices and measures to a case study: the Auckland Transport Alignment Project 2021–2031.

The report describes a framework and methodology that aims to provide a robust quantification of distributional effects of transport that can be incorporated into the MBCM. The method will help ensure equity effects are captured alongside other benefits, resulting in better and more well-informed decision-making.

1.2 Project background

The Waka Kotahi MBCM provides technical guidance and procedures for undertaking social cost–benefit analysis (CBA) of transport investments consistent with the Waka Kotahi Investment Assessment Framework. The MBCM acknowledges the importance of equity effects:

> *While an analysis of the distribution of benefits and costs among different groups of people is not required for economic efficiency analysis, evaluations of an activity should report the distribution of benefits and costs, particularly where they relate to the needs of transport disadvantaged populations.* (Waka Kotahi, 2020, p. 16)

At present, the Waka Kotahi MBCM does not provide a clear solution for capturing distributional effects:

> *This reporting forms a part of the funding allocation process. When it is required, distributional effects should be reported separately from, but alongside, the CBA results.* (Waka Kotahi, 2020, p. 16)

1.3 Policy context

This study researches the areas of social choice (how people choose what they do) and social welfare (how these individual actions combine to a collective wellbeing) overlaid with public choice (what policies to apply to improve social welfare).

In practical terms, a CBA for a transport project sits within tiers of public policies. These tiers in New Zealand are described in this section.

1.3.1 Living Standards Framework and Better Business Cases

The Treasury provides a pan-government policy approach, given its role as overseer of government funding allocation. Policy priority can vary because elected members of parliament change but a main focus across recent election cycles has been to raise the living standards of New Zealanders, applied through a Living Standards Framework (LSF),[1] and to undertake investment decisions in an objective manner, applied through the Better Business Cases (BBC) approach.[2]

Transportation infrastructure is a component of wealth, while transportation management is one of the institutional and governance arrangements that intermediate wealth and wellbeing within the LSF. The framework is not considered all-encompassing[3] but a core tool for developing robust and evidence-based public policy.

Pertinent to this study, the LSF recognises 12 domains as being core to the wellbeing of individuals and collectives of people; these include being healthy and safe and having access to a quality natural and built environment. An important influence on this multi-dimensional approach to wellbeing is the capability approach of Sen and Nussbaum, which is discussed in chapter 2. The measurement of attainment within these domains is undertaken by way of various indicators, including some aimed at identifying deprivation. The only indicator directly related to transport is a recently proposed measure of public transport accessibility: 'proportion of people aged 15+ finding it difficult or very difficult to use public transport (age standardised)'.

The LSF also includes four prompts as guides to assessment of policy impacts, that is, how policy will affect distribution, resilience, productivity (often measured by a CBA) and sustainability. The Treasury also provides a databank of policy effect estimates to be used within a CBA analysis, referred to as CBAx.[4]

A more thorough guide to the analytical assessment of public investment is provided by the BBC. Based on the United Kingdom (UK) five-case model, the BBC is generally needed for central government funding of major investments and provides the prototype for the Waka Kotahi allocation of hypothecated transport revenues, and is increasingly being used by local government in investment decision-making.

Components of the BBC related to this research project are the guides on benefit mapping, multi-criteria analysis and social CBA, which are discussed in chapter 2. It should be noted the current guide on equity is that any distributional consequence 'generally needs to be done separately from the CBA, but should be referred to in the CBA summary table' (New Zealand Treasury, 2015, p. 47).

The New Zealand Treasury's (2021) LSF intends to capture the issues that matter to New Zealanders' wellbeing, both now and in the future.[5] As shown in Figure 1.1, the LSF includes three outcome levels: aspects of life for individuals, the role of institutions in facilitating the wellbeing of individuals, and the wealth of the nation. Across these levels, the LSF introduced four analytical prompts that are the main lenses for analysing wellbeing (New Zealand Treasury, 2021, p. 16):

- Distribution: 'How is our aggregate wealth and wellbeing distributed across time, place and groups of people?'

---

[1] See www.treasury.govt.nz/information-and-services/nz-economy/higher-living-standards, for further information.

[2] See www.treasury.govt.nz/information-and-services/state-sector-leadership/investment-management/better-business-cases-bbc, for further information.

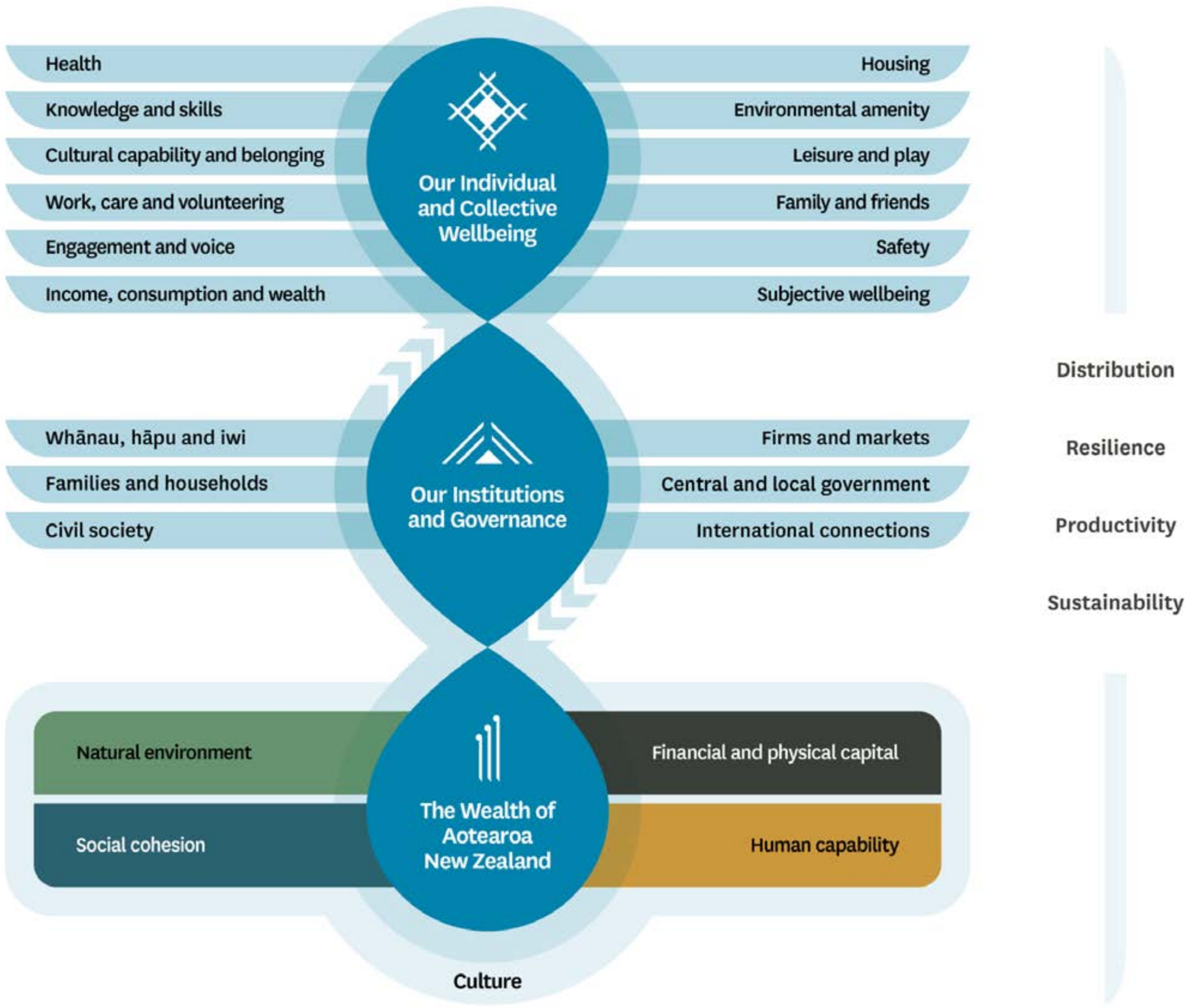
[3] For example, the Treasury also uses a waiora framework to consider a Māori perspective on wellbeing.

[4] See www.treasury.govt.nz/information-and-services/state-sector-leadership/investment-management/plan-investment-choices/cost-benefit-analysis-including-public-sector-discount-rates/treasurys-cbax-tool, for further information.

[5] A difficulty with using the Living Standards Framework for consideration of equity outcomes is its limited degree of spatial disaggregation.

- Resilience: 'Do individuals, collectives, institutions, organisations and the environment have an ability to adapt to or absorb stresses and shocks?'
- Productivity: 'How effectively is our wealth used to generate wellbeing and things of economic value?'
- Sustainability: 'How well are we safeguarding our national wealth for the benefit of future generations?'

Figure 1.1 New Zealand Treasury's Living Standards Framework

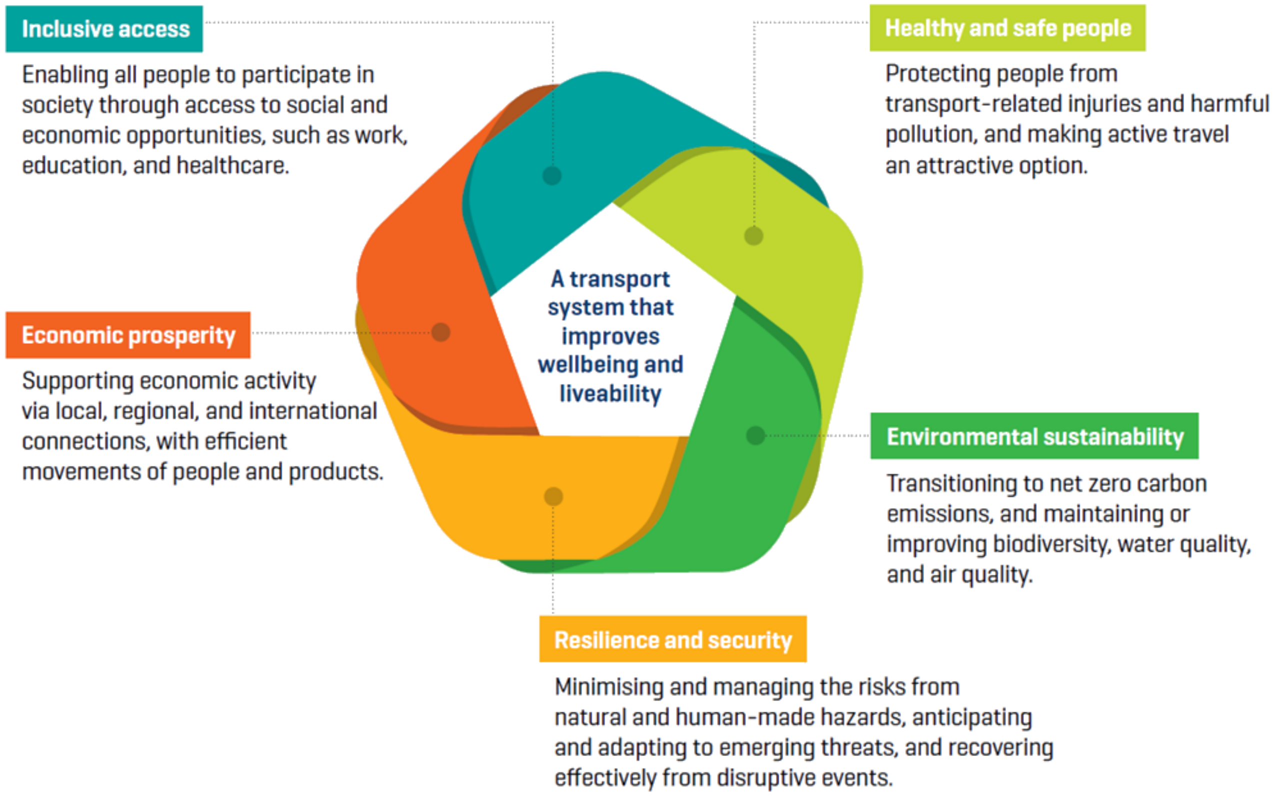


Source: Reprinted from New Zealand Treasury (2021, p. 2)

1.3.2 Government Policy Statement

The link between the LSF, key policies of the government of the day and land transportation is the Government Policy Statement (GPS) on land transport, presented as a three-yearly report. GPS 2021/22 to 2030/31 introduces improving people's wellbeing and the liveability of places as its purpose (New Zealand Government, 2020). Figure 1.2 shows the five main outcomes highlighted by the GPS to achieve a transport system that improves wellbeing and liveability. As shown in the inclusive access component, the GPS aims to improve accessibility for all people to be able to participate in society and benefit from economic opportunities. Accounting for equity leads to inclusive decision-making by accounting for the outcomes for all people and communities.

Figure 1.2 Transport outcomes framework



Source: Reprinted from New Zealand Government (2020, p. 5)

The recent change in transport policy focus from cars to people, with further emphasis on the aspects of liveability, is consistent with an international trend (Anciaes & Jones, 2020).

The Ministry of Transport prepares the GPS on behalf of the Minister of Transport. The Ministry of Transport also monitors Waka Kotahi.

1.3.3 Waka Kotahi

Waka Kotahi regulates the land transport system, manages the collection of hypothecated land transport charges, invests and distributes these funds – and other funds provided by central government from time to time – and manages the state highway network. The GPS sets the strategic direction for investment by Waka Kotahi, including quantifying the investment to be undertaken in 11 activity classes, including state highway improvements and coastal shipping. Waka Kotahi uses an investment decision-making framework to determine the projects and programmes that will be undertaken within each activity class. A CBA sits within this process and is required within the economic business case.

Waka Kotahi operates under the Land Transport Management Act 2003. The Act requires the Agency to 'exhibit a sense of social and environmental responsibility' (section 96) and, of direct relevance to project appraisal, to 'consider the needs of persons who are transport-disadvantaged' (section 35).[6]

[6] For further information, see https://www.legislation.govt.nz/act/public/2003/0118/latest/DLM227525.html?search=sw_096be8ed81bf29f2_disadvantage_25_se&p=1&sr=2

To provide useful decision support information, transport appraisals must account for the outcomes sought by policies, which constantly evolve over time. Albuquerque (2013) discussed that the Waka Kotahi transport appraisal frameworks account for the shortcomings of the standard CBA by including strategic fit and effectiveness criteria in the selection process. Strategic fit scores the consistency of policies with government policy statement priorities, and effectiveness ensures whole-of-system options have been considered.

1.3.4 Local Government Act 2002

While a large proportion of transport infrastructure in New Zealand is funded through Waka Kotahi, local government both manages and jointly funds local roads and local public transport systems. The heavy reliance on Waka Kotahi-approved funding creates an alignment in decision-making, but local government also has its own legislation. This specifies its purpose as including ‘to promote the social, economic, environmental, and cultural well-being of communities in the present and for the future’ (section 10(1)(b)) according to principles that include ‘when making a decision, a local authority should take account of – (i) the diversity of the community, and the community’s interests, within its district or region; and (ii) the interests of future as well as current communities; and (iii) the likely impact of any decision on each aspect of well-being’ (as referred to within the purpose statement above) (section 14(c)(i)–(iii)). In other words, the distribution of benefits is intended as an important input into local government transport investment decisions.

1.3.5 National Policy Statement on Urban Development

The National Policy Statement on Urban Development 2020 (NPS-UD) (Ministry for the Environment, 2020) is another influential part of government at present, and could be a potential beneficiary of findings from this research project. The NPS-UD tasks local councils with ensuring well-functioning urban environments that ‘enable all people and communities to provide for their social, economic, and cultural wellbeing, and for their health and safety, now and into the future’ (p. 10). To achieve this, the NPS-UD requires councils to account for proximity to transport corridors in their short-, medium- and long-term plans. Transport equity plays a significant role in sustainable urban development, which needs to account for the connection between location of jobs and housing for different socioeconomic groups.

Given the overlapping effects of transport, housing and taxing policies, a comprehensive policy framework needs to consider all these elements. Transport investment initiatives are associated with improved quality of living environment, which can lead to the displacement of lower income groups, a process known as (transit-induced) gentrification.[7] This is partly because house prices (and housing costs) act as an aggregator of the value of access to the amenities and facilities. With increases in the costs of housing, those with a lower affordability level move out, which leads to social exclusion.

1.4 Methodology

We followed a four-step process for finding studies to complete a systematic review of the literature:

1. Reviewing existing practices adopted internationally for assessing distributional and equity impacts and methods for mitigation from adverse impacts of transport intervention and initiatives.
2. Reviewing the academic literature sources adopted in the development of international standards for assessing distributional and equity impacts for the purpose of transport intervention and initiatives and methods for mitigation from adverse impacts.

[7] Stroombergen et al. (2021) revealed results within New Zealand cities consistent with movement of lower-income groups from areas of improved accessibility, although movement was not measured.

3. Using independent research search engines and databases, such as Econlit, SAGE, Proquest, Ebsco, Google Scholar, and a general Google search, to find other relevant academic and policy literature.
4. Using inputs from the project Steering Group and peer reviewers.
5. Contacting relevant organisations and authors of relevant research to learn about other (unpublished) available sources.

In our search for relevant literature, we used keywords to find the available studies from different search engines.

We use the literature review findings to inform our discussion of the appropriate methodology for the analysis of distributional effects in chapter 3.

1.5 Report contents

This research report is structured as follows:

- Chapter 2 provides an overview of our literature review on the assessment of equity effects in transport cost–benefit appraisals, including New Zealand and international approaches.
- Chapter 3 presents our assessment of the appropriate measure and methods for equity impact measurement within MBCM.
- Chapter 4 applies the framework and methods to a case study on the Auckland Transport Alignment Project 2021–2031.
- Chapter 5 concludes and discusses areas for further research.

A summary of the findings from the literature review is given at the beginning of each chapter.

2 Literature review

Extensive academic and policy discussions have been held about the role of equity effects in transport CBA appraisals. This chapter aims to provide a brief review of the most relevant discussions.

In New Zealand, two recent studies are closely related to the topic of this report. The first is Adli's (2019) doctoral thesis on inclusion of social justice in public transit planning, which reviews the theories of social justice in the domain of public transit and uses an empirical method for the assessment of equity effects. The second study is by Curl et al. (2020) on the social and distributional impacts of mode shift policies. That study reviews evidence available in New Zealand relating to three mode-shift policy levers, including shaping urban form to reduce the need for travel, making shared and active modes more transparent, and influencing travel demand and transport choices. The authors assess the potential social and distributional impacts of different policy levers.

In contrast to previous studies, our literature review further discusses the transport cost–benefit analysis framework, measurement of the impacts of equity effects within a CBA, and the Waka Kotahi MBCM.

Section 2.1 provides conceptual discussions about the role of equity effects in CBA. Section 2.2 discusses equity in the context of transport and the experience of other countries using equity considerations in transport CBA appraisal. Section 2.3 reviews the literature on the measurement of equity and section 2.4 reviews the methods of mitigation.

2.1 Cost–benefit analysis

2.1.1 Summary

Many studies focus on the challenge of assessing equity in the domain of transportation, however, the discussion on the implications of transport equity for CBA is limited. Conceptually, CBA is not concerned with distributional effects. For transport policy, however, the equity effects play a significant role in decision-making. This is because the benefits of transport investment are not necessarily distributed equally, due to differences in affordability and accessibility to the provided goods and services, which (often) leads to unintended social outcomes. So, from a public policy perspective, it is sometimes important to account for distributional effects.

2.1.2 Introduction

CBA assesses the economic efficiency of proposed policies or programmes through the systematic prediction and valuation (that is, monetisation) of all costs and benefits to all members of society (Boardman, 2015). CBA is based on modern welfare economics, which is based on the neoclassical economic theory that guides market analysis. Modern welfare economics is based on a utilitarian approach, which aims to maximise the utility of all individuals equally (Adler, 2016). CBA is the widely used standard for appraising whether a general project will provide value for money, applied in both the public and private sectors, including for transport investments. Several features of CBA are, however, relevant for the following discussion of equity effects.

The principle of Pareto efficiency lies at the heart of welfare economics (see Schumpeter, 1949). An allocation of goods is Pareto efficient if no alternative allocation exists that makes at least one person better off without making anyone else worse off. A reallocation of resources is a Kaldor–Hicks improvement if those who are made better off could compensate those who are made worse off and lead to a Pareto-improving outcome. The Kaldor–Hicks improvement is applicable to more circumstances because it is less stringent in comparison with the Pareto-efficient improvement. This is because the Kaldor–Hicks improvement can leave some people worse off, but in the Pareto-efficient improvement the reallocation should be such that at least one person is made better off and no one is made worse off. Many economic textbooks, therefore, focus on Kaldor-Hicks improvement for discussions of policy decisions.

A standard cost–benefit analysis assumes an intervention does not lead to significant changes in the distribution and growth of population and employment.[8] The assumption is that population and employment do not change between the do-minimum option and the proposed activity. Hence, the economic gains estimated in a standard transport CBA are based purely on increased cost efficiency mainly driven by travel time savings.

In CBA, accounting for distributional effects acts as a tax on high-income groups and a subsidy to the low-income (disadvantaged) group of the society.[9] A government intervention in the economy, such as a taxing policy or an infrastructure investment, often leads to redistribution of resources away from their free market use. This leads to market inefficiency, which means goods within the market are either overvalued or undervalued. The outcomes of market inefficiency lead to gains for some members of society and losses to others. This is associated with supply and demand of goods or services not being in equilibrium, which leads to a deadweight loss, so the standard CBA approach underestimates (or does not account for) the benefits from a transport investment with significant distributional effects (for business activities and communities).

Typically, the objective of private sector investments is to maximise wealth, which is taken to be the company value in the corporate world (Pike, 2015). The objectives in the public sector are generally wider and, as seen in section 1.3, often involve wellbeing; hence the reference to a social CBA.

So, what is this wellbeing that is being optimised in some way?

2.1.2.1 Are people the judge of their own wellbeing?

An important feature of the social CBA is that it stems from the philosophical approach of consequentialism whereby we assume we can assess the wellbeing effect of any change by focusing on its outcome. Furthermore, we can assess the wellbeing effect of any outcome change by measuring peoples' preferences; for example, would Chris prefer to take the car to work or the bus? The next step requires summing these preferences across the population. Here, CBA is based on a utilitarian assumption, namely that each person's gain in wellbeing is given the same weight as that of another person (Adler, 2019).

An alternative philosophical approach is to emphasise the deontological considerations around any change (Adler, 2019). For example, it may not be considered ethical to increase hedonistic consumption if it means some children miss out on schooling. An offshoot of this approach is for policy makers to focus on peoples' capabilities, a line of thinking that informs the LSF (Jensen & Thompson, 2020).

The philosophical debate is ongoing as to what constitutes wellbeing and whether we know our own wellbeing better than others. For this study, it is simply noted that the individual preference-based, equal person-weighted approach forms the basis of many global social and economic appraisals, and measurements such as life satisfaction surveys, which are also based on individuals' self-assessments, provide meaningful results (Grimes, 2019). This approach, however, may not be appropriate in all

[8] Cost–benefit analysis (CBA) applies to marginal changes in all variables, not just population and employment.

[9] A utilitarian approach requires each person's utility to be weighted equally. An unweighted CBA based on monetary equivalents does not do that. Using equity weights is a method for correcting for this measurement bias. Therefore, accounting for equity in a CBA appraisal does not necessarily mean taking resources away from the rich. It is often to correct for the pitfalls of a CBA appraisal.

circumstances. For example, there will be times when it is simply inadmissible to net off one person's wellbeing against another's.[10]

2.1.2.2 Current situation is taken as given, whether it be equitable or unequitable

A second feature is that CBA is an incremental approach. No consideration is given in the CBA to the rights or wrong, or preferences about, the existing distribution of consumption, wealth and capabilities. The social CBA simply sets out to measure whether a policy change, such as a new road, will lead to an improvement in total (discussed next).

2.1.2.3 Comparison of benefits and costs occurs in money terms

An important step in the social CBA is to compare the effect of any change on people in money terms, which is considered to be the monetary equivalent of the net utility gain (Adler, 2019). The monetarisation of changes in consumption and non-consumption bundles is an eloquent way to quantify how people will react to change. A positive net present value (NPV) implies that people, on aggregate, are willing to give up some of their current wealth for the changes being proposed because they, again collectively, feel they will be better off. More precisely, the analyst infers from the evidence available of individual preferences[11] that the population of interest will feel better off. Heavy reliance is then placed on the potential for people to redistribute this net benefit in a way that suits the population, either by fiat or bargaining, although this rarely occurs in practice (Hickman & Dean, 2018). Putting aside the equity impacts of any failure to redistribute benefits, a CBA as described does not compare peoples' utility (or wellbeing more generally). It is possible to map these changes in money values to the utility values for each person, as explained by Adler (2016) and as has been applied by Dennig (2018) in climate change work for groups of people. However, as Boardman et al. (2020) point out, this requires some (informed) assumption about the utility mapping function and a formidable amount of information about the people involved. This is not a reason to avoid mapping money to utility, or reweighting a CBA to use the industry terminology, but it is a warning that many challenges still exist. The research within the LSF has increased the information available on people and wellbeing in New Zealand, including within the CBAx database. The New Zealand Institute of Economic Research's (NZIER, 2018) review of the CBAx approach refers to the 'lack of knowledge about the target population' (p. 14) for the impacts identified across agencies' databases, which implies the information challenge that currently exists in New Zealand.

2.1.2.4 A transport CBA takes measurements from the primary market

Another feature of a transport social CBA is that the aggregate of benefits and costs to the population can be inferred from measurements in the transport market itself (Jara-Diaz, 1986). This simplifies the data requirement immensely. An outcome of this approach, however, is that the transport CBA does not identify the impact of a transport intervention; it simply states that a net positive NPV project will produce a net monetary benefit to the population, but makes no attempt to describe how these gains will manifest in the economy and community. For example, a reduction in travel costs may lead transport users to earn more profits or take more leisure, or the benefits of lower transport costs could pass to the consumers of products in the form of lower product prices. In other words, the benefit could fall to people who are not transport users and who are not in the vicinity of the to-be-improved transport link.[12] This adds to the information challenge if the distribution of benefits is to be disaggregated within the CBA, because considerations of the

[10] A further fundamental challenge is Arrow's Impossibility Theorem when only the ordering of individual preferences (ie ordinal measures) is known (as opposed to when cardinal measures of preferences, such as monetary equivalents, are available) (Adler, 2019).

[11] In practice, these are often households not individuals (Beyazit, 2011).

[12] This point was also raised by Wallis (2009).

economy-wide benefits and wider economic impacts (WEIs) and other externalities would be required. Economy-wide benefits are those driven from interactions among businesses, households and the government. WEIs are defined as 'benefits additional to user benefits arising as a consequence of failures in markets impacted upon by the transport intervention' (Laird & Mackie, 2009, p. 3). We discuss economy-wide benefits and WEIs further in section 2.3.6.

Boardman et al. (2011) show that any change in social welfare can be measured in the primary market, such as the transport market, when prices in other markets are unchanged, as is likely when the transport intervention is small. Likewise, if prices in secondary markets change, the total social welfare effects will be measured in the transport markets when markets are perfectly competitive. Both results depend on conditions of perfect competition outside the transport sector and so exclude the effects of externalities.

Jara-Diaz (1986) reduced the issue to elasticity of demand functions. He took a goods market that is independent of other markets and showed that the consumer surplus in each location will equal the surplus in the adjoining transport market for perfectly competitive markets, but not necessarily be equal for monopolistic markets. He inferred the defining factor as the degree of elasticity of demand. That is, if demand is elastic, as per perfect competition, then a change of consumer surplus in the transport market will approach the change in consumer surpluses in the two locations for the given goods market and could otherwise be above or below the sum of changes in non-transport consumer surpluses.

2.1.2.5 A New Zealand transport cost–benefit analysis already adjusts for equity

In principle, the money value each transport user places on such things as travel time and risk of death will be applied when calculating their benefits and costs. Unsurprisingly, it can be shown that wealthier people are willing to pay a higher amount for their time compared with people with little wealth (Athira et al., 2016). In practice, transport agencies, including Waka Kotahi, require that the same values are used for all transport users of a similar nature. For example, a car driver is ascribed a 2002 value of $7.80 per hour if commuting to and from work, $23.85 if on a business trip and $6.90 for other travel purposes (Waka Kotahi, 2021b). This is equivalent to a form of distributional reweighting, implicitly acknowledging that the utility of the less wealthy is relatively higher than their ability to pay and, conversely, the utility of the wealthy is relatively less. Any further distributional weighting of a CBA would need to consider this current implicit reweighting.

2.1.3 Role of distributional effects in cost–benefit analysis

While the Pareto efficiency principle is important to keep in mind for CBA, it does not provide a useful basis for evaluating public policy because most government interventions benefit some groups of society at a cost to others.

This Pareto efficiency limitation led to further efforts to develop a criterion with more general applicability to actual policy decisions. This resulted in the 'potential Pareto improvement' criterion, which says a potential Pareto improvement exists when the allocation of resources allows those who gain to compensate for those who lose, and still be better off. If an intervention is potentially Pareto-efficient, it leads to potential economic efficiencies, which is called 'allocative efficiency'.

As typically applied, CBA assumes the marginal utility of income or wealth is equal across all members of society. This implies the utility gains from an additional dollar are equal for poor and rich people. As Boardman (2015, p. 48) explained:

> *a project that transfers a fixed amount of money from one person to another or from one group of people to another group is, from the perspective of CBA, simply a transfer and has a net benefit of zero (ignoring transaction costs). […] In summary, CBA concerns allocative efficiency, not equity.*

A range of empirical research supports the conceptual argument of the importance of accounting for distributional effects in evaluations of transport policies. Abulibdeh (2013) studied the importance of equity effects in a CBA of road pricing policy in the Greater Toronto Area (Canada). For his evaluation, he considered the vertical equity type[13] as well as individuals' perceptions about the equity of cordon pricing.[14] The results suggest a cordon pricing scheme in downtown Toronto has progressive effects on the various socioeconomic groups. The effects are progressive across different age groups, gender, household sizes and occupational categories. Chadwick (2021) assessed the impact of light rail in the UK. His results suggest that higher income groups have a higher propensity to use light rail and benefit more from it. This is because the high-paid jobs are located in the city centre, and light rail serves the city centre markets the most.[15] Chadwick accounted for changes in congestion resulting from the adoption of light rail, and its impact on the number of accidents and the environment.

Using distributional weights (which we present in section 2.4.4) raises questions about the institutional role (of the government). Adler (2016) provides a logical framework for the arguments around using distributional weights in the CBA. He concludes (p. 280) that 'the use of weights requires an ethical/moral judgement, but so does the decision to use unweighted CBA'.

It is possible to argue that reallocating one dollar to the low-income group may be associated with taking more than one dollar away from the high-income group (Boardman, 2018). However, many government policies are associated with redistribution of income from high- to low-income groups. The Ministry of Social Development's Work and Income programme is an example of the government's redistribution of income policies. Therefore, society seems to be willing to sacrifice some efficiency to help the low-income (or disadvantaged) group.

2.1.4 Incorporation of distributional impacts

As discussed, CBA may be inappropriate for measuring distributional impacts given its focus on economic efficiency (Browne & Ryan, 2011; van Wee & Geurs, 2011). Various methods have been suggested for incorporating distributional effects into CBA. Three components of CBA need to be carefully considered in relation to equity effects:

- Equity value of time: CBA uses the same value of time for all population groups in converting time saving to monetary values. This approach does not account for the fact that people of a higher socioeconomic level may benefit from the transport project more (because they make more trips and have higher willingness to pay for the outcomes), while the lower socioeconomic groups may suffer from low accessibility (Martens & Di Ciommo, 2017).
- Discount rate: By using a discount rate, the outcomes with different time spans will be compared on a common present value basis.[16] The discount rate captures the marginal social opportunity cost of funds allocated to public investment. A high (low) discount rate is in favour of policy decisions that deliver outcomes in the short (long) term. Therefore, finding the correct discount rate is crucial for successful decision-making that highlights the needs of the community (and not the policy maker or analyst). Given

[13] Vertical equity considers the distribution of the effects of an action among individuals, groups or geographical areas that differ in needs and abilities.

[14] Cordon pricing is a form of road pricing intended to reduce traffic in dense urban areas, such as city centres or central business districts.

[15] The move to more productive (higher paid) jobs may lead to increased taxes, which is a benefit. So, the outcomes include both positive and negative impacts and depend on particular circumstances.

[16] Discounting is used to achieve a consistent comparison between costs and benefits of outcomes occur during different time spans.

the longer time span of transport investments, the choice of discount rate has a significant effect on the efficiency of projects and on intergenerational equity effects (Di Ciommo et al., 2014; Guzmán et al., 2013).

- The life cycle used in CBA for the calculation of benefits: The life cycle affects the net present value of a given project, because most fixed costs will occur in the short term, whereas many of the benefits, particularly the social impacts,[17] are likely to be realised in the longer term (Browne & Ryan, 2011). The time horizon often varies between countries (Odgaard et al., 2006).

Using these components of CBA, attempts have been made to account for equity effects within CBA frameworks. However, there is agreement that the equity effects fit alongside the indirect (or wider) impacts of transport investments, which are difficult to measure within a conventional CBA. As we discuss in section 2.4, the most useful outcome of the attempts for capturing transport equity effects is to use multi-criteria assessment and CBA together (Di Ciommo & Shiftan, 2017; Thomopoulos et al., 2013). This conclusion is consistent with the New Zealand Treasury's (2015) *Guide to Social Cost Benefit Analysis*, which recommends that 'where projects or options have significant favourable or unfavourable distributional consequences, that they be analysed separately in terms of their relationship to wider government distributional policies and drawn to decision-makers' attention' (p. 47).

The range of impacts is limited that could be robustly monetised within a CBA, particularly for the intangible social, environmental and cultural impacts (Beuthe, 2002; Grant-Muller, 2004; Johansson-Stenman, 1998; Shang et al., 2004). Therefore, many evaluations consider accounting for WEIs.

2.1.5 Equity considerations

CBA is a method for assessing the economic efficiency of proposed policies or programmes through the systematic prediction and valuation (that is, monetisation) of all costs and benefits to all members of society (Boardman, 2015). CBA is developed based on modern welfare economics, which is based on the neoclassical economic theory that guides market analysis. Modern welfare economics is based on a utilitarian approach,[18] which aims to maximise the utility of all individuals equally.

The use of distributional weights acknowledges differences in the social marginal utility of income, assuming one dollar to lower income groups increases social welfare more than one dollar to higher income groups. A crucial issue in using distributional weights is whether the economic pie is smaller or larger through their use. In other words, the use of distributional weights may lead to an increase in equity at the cost of efficiency. Though this is not always the case, sometimes the opposite is true, where using distributional weights leads to a more optimal outcome (Johansson-Stenman, 2005).

2.2 Transport and equity

2.2.1 Summary

Transport equity discussions focus on social justice. For the measurement of equity, it is necessary to identify the equity type and segment of society affected by an intervention, and identify and measure the range of outcomes. Amongst the theories of justice, further emphasis has recently been put on Sen's capability approach, which includes individuals' ability to move freely from place to place to improve their

[17] Social impacts include the experience of the transport system and its impact on social factors, excluding the economic or environmental impacts. Larger infrastructure investment, in particular, has unevenly distributed social impacts at the local scale. This is partly because projects are assessed using high-level budget and time metrics, without considering impacts at the community level (Mottee et al., 2020). Groth (2019) found that the most well-off people experienced benefits of shifts to multi-modality and smart mobility, while those worst off were excluded due to affordability.

[18] For a definition, see section 2.1.

'capabilities' and achieve their 'functionings'. For the population groups, several segments have been considered in the literature. The most common feature considered for the definition of population groups was income levels. For identifying impacts, accessibility impacts of transport initiative investments have been widely used in the literature.

One distinction made is that between 'process equity' and 'outcome equity' (Levinson, 2010), with the former favouring wide participation of the people affected by the transport proposal as opposed to the outcome of any change. This report focuses on outcome equity, to remain consistent with the approach of CBA.

2.2.2 Introduction

With the growth of car ownership in the 1960s and 1970s, policies focused on car-based mobility, which required investment in road and associated (car-parking) facilities. With increases in congestion, and the emergence of social and environmental side effects of car use, many governments restrained car use and concentrated on streets as places. This was associated with a further focus on road pricing and increases in road shares of cyclists and pedestrians, and improvement of the public realm. This change in policy paradigms increased the focus of transport policy on a healthy, equitable and sustainable transport system, which ultimately leads to improved quality of life and wellbeing (Appleyard et al., 2014).

2.2.3 What is transport equity?

The term 'social equity' (also called 'social justice' or 'fairness') refers to the distribution of effects (benefits and costs) and whether this is considered fair and appropriate (Litman, 2022).[19]

Transport equity discussions are concerned with the following questions:

1. Are resources allocated fairly? The resources include infrastructures, services and expenditures.
2. Does the transport system provide a fair opportunity to be mobile and have accessibility to important 'life chance' activities.[20]
3. Does the transport system design lead to adverse effects (negative externalities) for some population groups? The negative externalities include exposures to pollution, traffic-related risks and personal safety.
4. Is the decision-making process inclusive, providing opportunities for all communities to participate? This question emphasises further consideration of the outcomes for disadvantaged communities.

Justice has been referred to in different contexts, including legal, social, environmental, spatial, distributive and intergenerational. In the transport context, it is important to distinguish between legal and social justice. As noted by Lucas et al. (2019, p. 7), 'legal justice refers to "the proper administration of the law", whereas social justice is typically applied to concerns about the moral acceptability of a situation, often irrespective of its formal legality. In a "well-organised" society, legal justice is rooted in conceptions of social justice'. The discussion on transport equity focuses on social justice.

[19] In this report, the terms distributional effects and equity effects are used interchangeably. A clear definition of equity objectives for intervention would provide the necessary parameters and boundaries for how the impacts of interventions should be disaggregated to understand whether those objectives are met. This means when the equity objectives change (due to different circumstances underpinning an intervention), the way in which the distributive impact assessment is conducted may change.

[20] For discussions about mobility and accessibility, see section 2.2.6.

In addressing the issue around measurement of the distributional elements of transport equity, three components require examination:[21]

1. the benefits and costs being distributed
2. the populations and social groups over which they are distributed
3. the distributive principle that determines whether or not a given distribution is considered ‘morally proper’ and ‘socially acceptable’.

Specifically, three main underlying factors influence the relationship between transport and inequality (Gates et al., 2019):

1. the geographical distribution of different socioeconomic groups
2. the distribution of opportunities, including jobs and education
3. the accessibility provided by the transport system, in terms of cost, geographic accessibility, and the time and reliability of different transport options.

2.2.3.1 Equity, social norms and location choice

Kolm (1971, p. 228) defines equity as ‘no envy’, where ‘an allocation is envy-free if no individual would prefer having the bundle of another’.

Several reasons exist for why urban environments are segregated, including individual preferences (for closeness to specific amenities and facilities) and the constraints people face in their choice of location. Transportation acts as a facilitator in connecting people to places and helping them access life-enhancing activities, bringing them together. Transportation helps people overcome segregation and improves their chances of accessing opportunities and travel to places (Martens, 2017). Poor(er) accessibility of low-income groups leads them to a lower level of benefiting from goods and services and, ultimately, to social exclusion and persistence of poor conditions over long periods; these are also known as ‘poverty traps’ (Lucas, 2012; Torshizian, 2017).

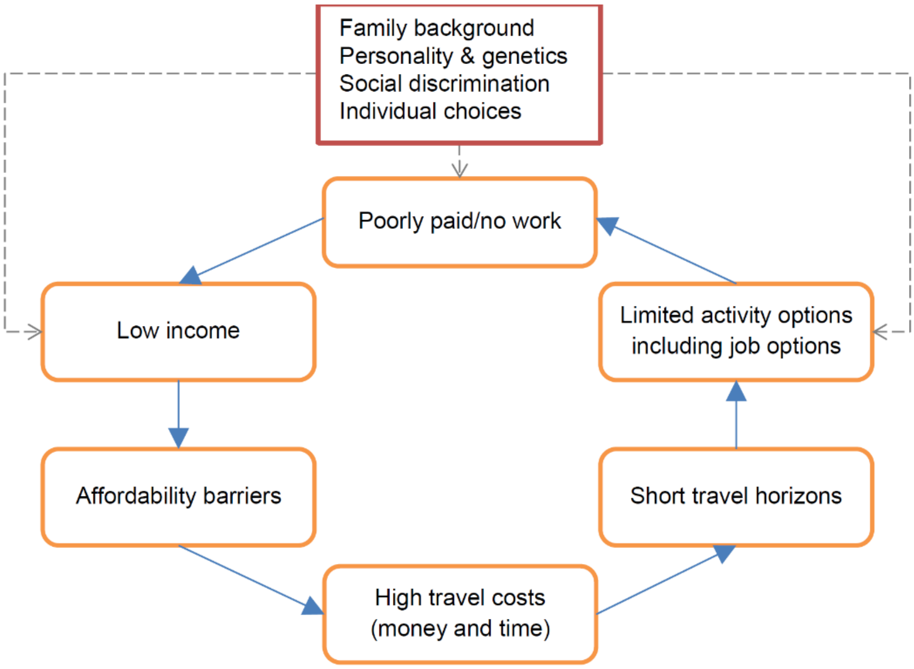
Stroombergen et al. (2018) discussed the impact of socioeconomic changes on the New Zealand land transport system. Their report suggests that clustering of households (and businesses) adds a layer of complexity to the estimated relationships between the improved features and the utility of households. Clustering acts as a third factor affecting both the improved features and outcomes of interest, including land values and wellbeing of residents.

Extensive discussions have been held about the role of transport infrastructure in providing equal accessibility to opportunities, mainly driven by the capability approach, as covered in the next section. Figure 2.1 outlines how individuals’ backgrounds and choices are associated with poorly paid jobs, which leads to affordability barriers in terms of the location of housing in relation to jobs and a cycle of transport poverty.[22] These discussions have led to the recent debate about levelling-up, which focuses the spread of opportunities more equally across different communities.

[21] This is similar to the process suggested by the Transportation Research Board & National Academies of Sciences, Engineering, and Medicine (2004).

[22] The concept of transport poverty refers to difficulty or inability to make necessary journeys due to a combination of income and cost and service availability.

Figure 2.1 Capabilities approach to wellbeing



Source: Reprinted from Gates et al. (2019, p. 4)

Torshizian (2017, pp. 183–199) studied the impact of proximity to less deprived locations on residential satisfaction of Auckland residents. After accounting for choice of location and other related factors driven by individuals' backgrounds, his results suggest that residents of poor (rich) areas are positively (negatively) affected by the affluence (poverty) of neighbouring areas, which confirms the presence of a positive amenity effect for residents of poor neighbourhoods and a negative 'not in my backyard' effect for residents of rich neighbourhoods. This difference in wellbeing outcomes for the residents of rich and poor neighbourhoods motivates moral arguments about the choice of theory of justice (and the role of public policy).

Torshizian (2017, pp. 229–230) constructed various relative measures to account for comparisons across socioeconomic groups (and capture that envy effect). The study also considered the level of living environment feature (for example, population density) that is socially accepted for an individual, based on their background. Torshizian's results suggest that, in the choice of location of living, people apply expectations based on their social norms when evaluating their living environment. After taking these social norms into account, people value living in less crowded houses, in less dense suburbs and in proximity to affluent areas.

Torshizian's findings (2017) show that the general norm for most within a society is not necessarily fair for everyone living within it. This has been further discussed by Lucas et al. (2010), who refer to an example of the norm for people in the Global North being to own and drive a car. Lucas et al. discuss that this norm does not follow that the best route for transport justice is to give everyone a car. For one reason, not everyone is able to drive and, for another, vehicle ownership can be a considerable burden on household finances. A conflicting issue is that road traffic also causes pedestrian and cyclist deaths, and pollution, which mostly adversely affects vulnerable members of society, who morally should be protected from harm.

2.2.4 Theories of justice and social equity approaches

Equity requires a moral judgement on whether the distribution of resources, impacts or outcomes is considered to be fair (Curl et al., 2020). As such, the evaluation of transport equity requires choosing a social equity approach that aligns with the social values and objectives of decision-makers and communities (Behbahani et al., 2019).

In this section, we present seven theories of justice and discuss justice in transport. We discuss the factors important for the choice of an equity approach in chapter 3.

2.2.4.1 Theories of justice

While a large number of theories of justice and social equity approaches exist, their relevance from a policy perspective can be broadly categorised based on their distributional outcome. Khisty (1996) and Behbahani et al. (2019) provide extensive discussions of theories of justice. Based on that, we have summarised eight commonly used approaches, as shown in Table 2.1. A more comprehensive list of equity justice is provided by Thomopoulos et al. (2009) (see Appendix A).

Table 2.1 Theories of justice[23]

Approach	Objective
Equal share distribution (egalitarianism)	Distribution based on an equal share, or as equal as possible among socioeconomic groups
Utilitarian distribution (utilitarianism)	Distribution based on maximising the benefits to the community as a whole
Maximising average net benefits with a minimum floor (sufficientarianism)	Distribution based on maximising average benefits while ensuring disadvantaged individuals or groups receive a minimum amount of benefit
Narrowing the gap in total final benefits	Distribution based on maximising average benefits while attempting not to allow changes in differences between individuals or groups to exceed a certain amount
Limiting the variance in added benefits	Distribution based on maximising the total final benefits with the consideration of limiting the variance in added benefits for all groups in the community
Narrowing the gap in final benefits	Distribution based on reducing existing social or economic inequalities
Rawls' theory of justice	Distribution based on maximising benefits to disadvantaged groups
Sadr's theory of justice	Distribution based on maximising average benefits while attempting not to allow changes in differences between individuals or groups to exceed a certain amount and ensuring disadvantaged individuals or groups receive a minimum amount of benefit

Source: Adapted from Khisty (1996, p. 2) and Behbahani et al. (2019, p. 8)[24]

With a slight difference from the other theories of justice, the capabilities approach focuses on the improvement of an individual's 'capabilities' or the range of things they can realistically do. In relation to transport, the capabilities approach relates to an individual's conversion factors, particularly their ability to move freely from place to place to improve their 'capabilities' and achieve their 'functionings' (Nussbaum, 1997, 2000, 2007; Sen, 1999). This approach has been used across various transport equity studies over the past decade (Hyard, 2012; Mella Lira, 2019; Nahmias-Biran & Shiftan, 2019).

Randal et al. (2020) note that limitations of access should not be the sole focus in transport justice, because one of the biggest issues of transport systems today is the mitigation of climate change and the social and health impacts of transport. They suggest that the capabilities approach, with a greater focus on conversion

[23] Approaches such as egalitarianism and utilitarianism fall under the classification of horizontal equity approach, while Rawls' and Sadr's theories of justice are vertical equity approaches.

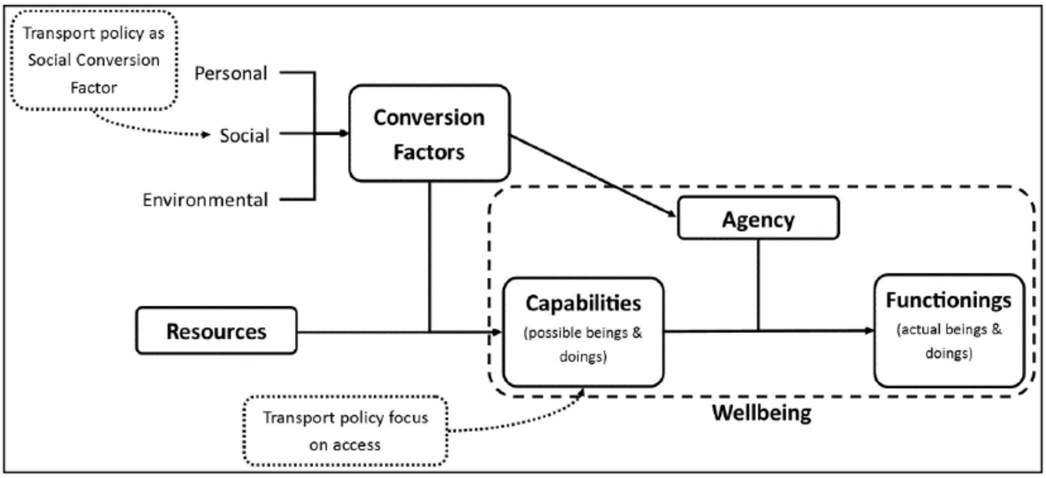
[24] Behbahani et al. (2019) provide mathematical formulations corresponding to different social equity problems in infrastructure investment. These are attached in Appendix B.

factors and structuring capabilities, is in line with te ao Māori and established concepts of Māori wellbeing to align with obligations under the Treaty of Waitangi. The authors cite the processes of ngā manukura (leadership) and te mana whakahaere (autonomy) as being complementary to the concept of agency under the capabilities approach (Durie, 1999). They suggest the adoption of a capabilities approach, including ngā manukura, mana whakahaere and accessibility, as part of capabilities but with a focus on conversion factors, would make 'it easier for policy makers to take into account dynamic non-linearities and feedback loops that are a part of all complex social-ecological systems' (Randal et al., 2020, p. 15).

Vecchio and Martens' (2021) review of the capability approach in transport literature aligns with the views of Randal et al. (2020). Vecchio and Martens found that authors tend to conceptualise mobility and accessibility as capabilities, and transport policy as conversion factors towards greater wellbeing.

Randal et al. (2020) produced a diagram showing how transport policy in general, and in regard to accessibility-focused policy, theoretically aligns within the capabilities approach. Figure 2.2 shows transport policy as a social conversion that allows individuals to better use their resources and improve their agency in achieving their functionings. Transport policy with a focus on accessibility improves individuals' capabilities, or, in other words, their possible beings and doings. This will lead to improved wellbeing outcomes.

Figure 2.2 Capabilities approach and transport policy



Source: Reprinted from Randal et al. (2020, p. 9)

2.2.4.2 Transport equity approaches

Based on the theories of justice, a variety of social equity approaches are relevant to the evaluation of transport initiatives. Lewis et al. (2021) reviewed equity measures in transport, considering terminology such as horizontal and vertical to be oversimplified classifications compared with theories of justice and adding to confusion of the transport equity discussion. While we agree with this to an extent, we have noted these classifications, given their presence and use in domestic and international policy documents.

Some of the most important forms of equity for transport initiatives are as follows (Litman, 2022; Transport and Infrastructure Council, 2016):

1. **Horizontal equity** concerns the distribution of effects of an action among individuals, groups or geographical areas considered equal in capabilities and requirements. According to this definition, equal groups and individuals should receive equal shares of resources, pay equal costs and be treated equally in other affairs. This means public policies should avoid favouring one person or group over others, and consumers should 'receive what they paid for and pay for what they received' unless subsidisation is justified (Khisty, 1996; Litman, 2022; NZ Transport Agency, 2018; Raux & Souche, 2004).

2. **Vertical equity** concerns the distribution of the effects of an action among individuals, groups or geographical areas that differ in needs and abilities. Based on this criterion, policies are considered equitable if they benefit physically, economically or socially disadvantaged groups or regions, and if they reduce the gap between advantaged and disadvantaged people (Khisty, 1996; Litman, 2022; NZ Transport Agency, 2018; Raux & Souche, 2004).
3. **Spatial or territorial equity**[25] refers to the provision of equal conditions for citizens living in all parts of the country. This principle is associated with the right to mobility and access to jobs, goods and services from any location (Raux & Souche, 2004).
4. **Intergenerational equity** refers to benefits from the various planned interventions addressing the needs of all. Accordingly, social impacts should not fall disproportionately on certain groups of the population, particularly children and women, the disabled and socially excluded, certain generations or certain regions (Vanclay, 2003).

Approaches such as egalitarianism and utilitarianism fall under the classification of horizontal equity, while Rawls' and Sadr's theories of justice are vertical equity approaches.

Which distribution theory to use depends on the policymaker and characteristics of the community that is represented (Khisty, 1996; Transport and Infrastructure Council, 2016). When people are influenced by the choice of equity types, or are offered several rules from which to choose, they tend to prefer the rule that favours them. Khisty (1996) suggests that citizens are generally not worried about ethical theories as much as they are concerned with their own welfare in terms of 'quality of life'. Therefore, Khisty defines 'quality of life' as the essence of the collective economic, social and physical conditions of people in a community. We discuss the choice of appropriate equity type in chapter 3.

2.2.4.3 Social justice in transport

Several prominent transport planning scholars have attempted to define a social equity approach specific to transport equity. These approaches tend to combine elements from more general approaches in social justice theory. Table 2.2 shows Adli and Chowdhury (2021) summary of how different authors have incorporated the general approaches into their viewpoint.

Table 2.2 Summary of work by key scholars in social justice in transportation planning

Key authors	Egalitarianism	Sufficientarianism	The right to the city[26]	Spatial justice
Lucas	Low-income people should not bear the burden	Transportation should not deny low-income people	Low-income people should participate in the decision-making process	Spatial impact of decisions should be available
Martens		The range below the threshold of sufficient accessibility is the domain of justice	Interventions are only acceptable if they do not increase the suffering from insufficient accessibility	
Pereira	Transport policy is fair if it distributes transport investments and services in ways that reduce inequality of opportunity	Minimum standards of accessibility should be set for key destinations	Individuals' basic rights and liberties should never be violated	

Source: Adapted from Adli & Chowdhury (2021, p. 5)

[25] Soja (2010) suggests social justice theory should be expanded by adding a spatial dimension that recognises how spaces encompass and influence individuals within them.

[26] Adli (2019) identifies two principles under Lefebvre's (1968) notion of the right to the city: the right to participation and the right to appropriation (in relation to the urban environment).

Lucas (2004) identifies how low-income households are significantly less likely than high-income households to be car owners and suggests that mass car ownership, combined with other economic and socio-demographic changes, has led to a more dispersed urban development. This has resulted in the concentration of low-income groups in areas being affected by negative impacts from car use, such as accidents and traffic-related pollution. Subsequently, the dynamics of car ownership have led to increasing social exclusion and diminishing accessibility of low-income households. In Lucas's (2004) view, transport justice should focus on the impacts, outcomes and participation of low-income households in the decision-making process.

Pereira et al. (2017) propose a transport equity framework aligning with approaches following Rawls' (1999) theory of justice and Sen's (1999) capabilities approach. Pereira et al. (2017) suggest access to important destinations is a basic capability to satisfy people's needs, so a minimum level of accessibility should be set and guaranteed by policies, if necessary. An individual's basic rights and liberties should not be infringed upon to improve the accessibility of others. When aiming to improve overall accessibility, policies should prioritise vulnerable groups and mitigate any arbitrary disadvantages that reduce their accessibility levels. The highest level of accessibility of social groups and modes should only be limited if a marginal improvement of accessibility at the upper levels would harm those groups at the bottom.

For further discussion on social justice in transport, see Appendix C.

2.2.5 Equity impacts

Many transport plans, strategies and policies have articulated equity as an important issue to consider in transport infrastructure investments. For example, in 2003, a draft transport plan from the South Australian Government (2003, p. 7) notes 'transport's contribution to social inclusion through recognition that not all South Australians fare equally and some experience acute and disproportionate disadvantage'. The following groups were subsequently recommended for closer attention in any distributional analysis (Australian Government, 2020):

- Age (the 2003 South Australian Government report specifically mentions the mobility needs of older people and the young who are especially dependent on public transport and others for transport)
- Gender (the 2003 South Australian Government report specifically mentions people who have particular travel needs regarding access to private transport and in patterns of commuting and employment)
- People with disabilities[27]
- Indigenous people
- Regionally and geographically disparate groups
- Income and wealth cohorts
- Businesses by size
- People with different cultural backgrounds and immigration status.

Household income is both an input and output of the location of households. Holding all else constant, high-income households outbid lower income groups in areas with higher amenities, leading to the spatial segregation of households by income (Mieszkowski & Mills, 1993; Roback, 1982). Low-income households,

[27] Torshizian (2019) investigated whether increases in housing costs in Auckland had greater impacts on individuals with chronic health conditions, compared with the rest of the population, in terms of where they choose to live. His results suggest that people with chronic health conditions will remain closer to a hospital despite paying higher rents. This may suggest that a sustainable transport investment needs to account for the accessibility of people with health conditions.

at least in the United States of America (US) and UK, are significantly less likely to own a car than higher-income households (Lucas, 2004).

MRCagney (2020) investigated transport equity in Auckland's transport system. The report investigates seven groups that may experience transport inequality: Māori, low-income people, women, LGBTQI+ people, disabled people, older people and ethnic minority groups. MRCagney reviewed previous studies and suggest that income inequality results in transport inequality for all investigated groups. Their literature review does not provide information about the strength of the link between transport inequity and income. However, low income stands as a co-factor of transport inequity.

Currie et al. (2010) investigated the relationship among wellbeing, social exclusion and transport disadvantage in Melbourne, Australia. They found that low-income households without a car make a trade-off in their home location to balance mobility and accessibility. By contrast, low-income fringe households with high car ownership were found to be more concerned about housing affordability and natural amenities than those in areas with transport. Other households without cars on the urban fringe balance accessibility by living close to activity centres. Currie et al. identify four underlying factors of transport disadvantage experienced by groups and individuals: transit disadvantage, transport disadvantaged, vulnerable/impaired and rely on others. Transport disadvantage can relate to both socially advantaged and disadvantaged groups though time poverty.

Delbosc and Currie (2011b) studied the relationship between transport disadvantage and social exclusion on wellbeing in Victoria, Australia. The authors found that people facing transport disadvantage experience lower wellbeing (7.0 out of 10, compared with an average of 7.6), while those facing transport disadvantage and social exclusion experience even lower wellbeing (5.3 out of 10).[28] Furthermore, people who faced transport disadvantage and social exclusion were more likely to be unemployed, a lone parent, receive a disability pension and not own a car.

The Transport and Infrastructure Council (2016) provides a list of variables that could be used to define a community social profile. We note the most related factors in Table 2.3.

Table 2.3 Variables used to define a community social profile

Characteristic	Variable	Examples of measures of variables
Socioeconomic status	Income	• Median income of families and individuals • % of families below poverty level
	Education	• Education and median years of education completed
	Employment	• % in occupational categories • % employment by type and location • % unemployment status of employment (temporary or long term)
	Mobility characteristics	• Car ownership and availability • Use of alternative and non-motorised modes
Demographic factors	Population	• Total population • Population density
	Ethnic composition	• % of population from different ethnic groups
	Age composition	• % in 10-year age categories
	Homeowner and/or renter composition	• % housing owner occupied • % housing renter occupied

[28] The results indicate an association between transport disadvantage and social exclusion – ie, causality indetermined.

Characteristic	Variable	Examples of measures of variables
	Housing quality	• % houses • % units or apartments • % public housing
	Housing value	• Median house value • Median rent
	Residential stability	• % with more than five years in residence • % with less than10 years in residence
	Household size	• % single person households • Median household size
	Household composition	• % households with husband and wife • % single parent households with children
Land use	Nature of land use	• Total land area of community • % residential • % recreational • % commercial • % industrial • % vacant and farm
Community institutions	Religious	• Number, type and location of institutions • Patterns of use of institutions
	Government services including libraries, police stations and so on	
	Commercial	
	Education, including child care	
	Health facilities	
	Recreation facilities	

Source: Adapted from Transport and Infrastructure Council (2016, p. 14)

Sanchez et al. (2003) provide detail on how minorities have suffered inequitable effects from the US transport system in many ways.

2.2.6 Mobility and accessibility

Curl et al. (2020) provide a brief review of the identification and measurement of social and distributional effects in transport appraisals in different countries. As they note, traditional transport appraisal methods prioritise mobility over accessibility.

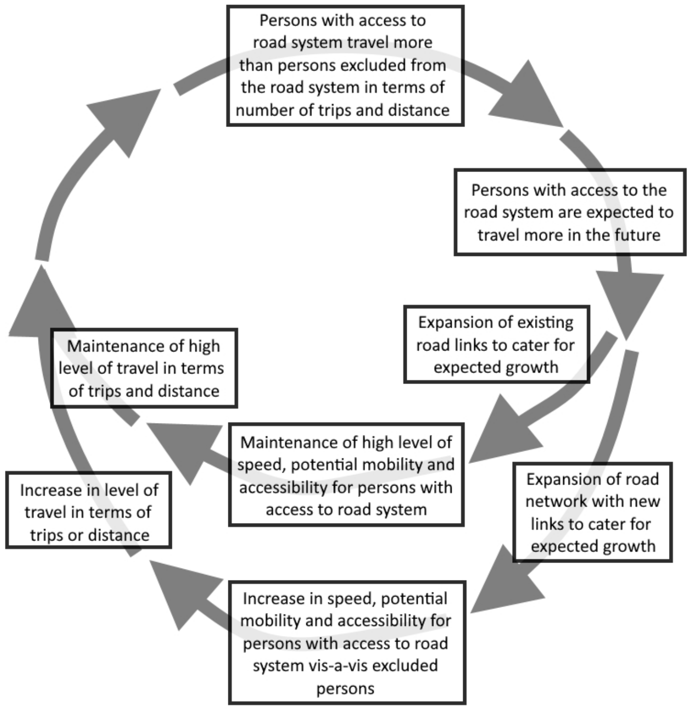
Mobility and accessibility have subtle but important differences in meaning that are relevant to evaluation of transport equity. Where mobility is defined as ‘the ease with which a person can move through space’, accessibility is ‘the potential for interaction with locations dispersed over space’ (Martens, 2017, p. 40).[29] In other words, accessibility is where an individual can potentially travel, and mobility is the revealed travel preferences based on their accessibility.

[29] This is similar to Litman’s (2022) definition of accessibility as ‘people’s ability to reach goods, services and activities’, which is the ultimate goal of most transport activity.

> *Accessibility is fundamentally about the life opportunities open to people. It is not a sufficient condition for social inclusion and social justice, but it is a necessary one.* (Farrington & Farrington, 2005, p. 10)

Martens (2017) highlights how planning for increased mobility can lead to inequalities in accessibility. This can arise from transport planning using 'revealed mobility as a representation of choice' reinforcing existing accessibility inequalities and increased inequality in potential mobility (p. 54). Figure 2.3 shows how this process can occur within traditional transport planning conventions.

Figure 2.3 Adverse transport mobility planning cycle



Source: Adapted from Martens (2017, p. 61) adapting Martens (2004)

Accessibility has persistent spatial socioeconomic effects over time (Dong et al., 2006; Farrington & Farrington, 2005; Soja, 2010). Åslund et al. (2010) studied the relationship between accessibility and employment for refugees in Sweden. Their results suggest that refugees who were initially housed in locations with lower levels of accessibility to jobs had lower levels of employment nine years later.

The Department for Transport UK (2020a) cites in its TAG Unit A4.1 Social Impact Appraisal the five main barriers identified by the Social Exclusion Unit in *Making the Connections* (2003) that affect accessibility:

- The availability and physical accessibility of transport
- Cost of transport
- Services and activities located in inaccessible places, the developments, including housing, hospitals, business and retail, are often located in areas not easily accessible to people without a car
- Safety and security, particularly in terms of not using public transport or walking to key services because of the fear of crime or anti-social behaviour
- Travel horizons and unwillingness to travel because of long journey times or distances or lack of knowledge about transport services.

A challenge when using accessibility metrics for measuring distribution of accessibility is that the metrics assume everybody is affected by transport in the same way. Using accessibility as the indicator of equity tends to ignore the distribution of other impacts. For example, using average walk speed to reach bus stops as a measure of access to public transport may underestimate the time taken by older adults. This will lead to an incorrect assumption about the older people's levels of accessibility.

Table 2.4 lists variables for measuring accessibility and quality of transit services. We have also included measures for associated environmental and social stress factors.

Table 2.4 List of benefits and impacts for measuring accessibility and quality of transit services

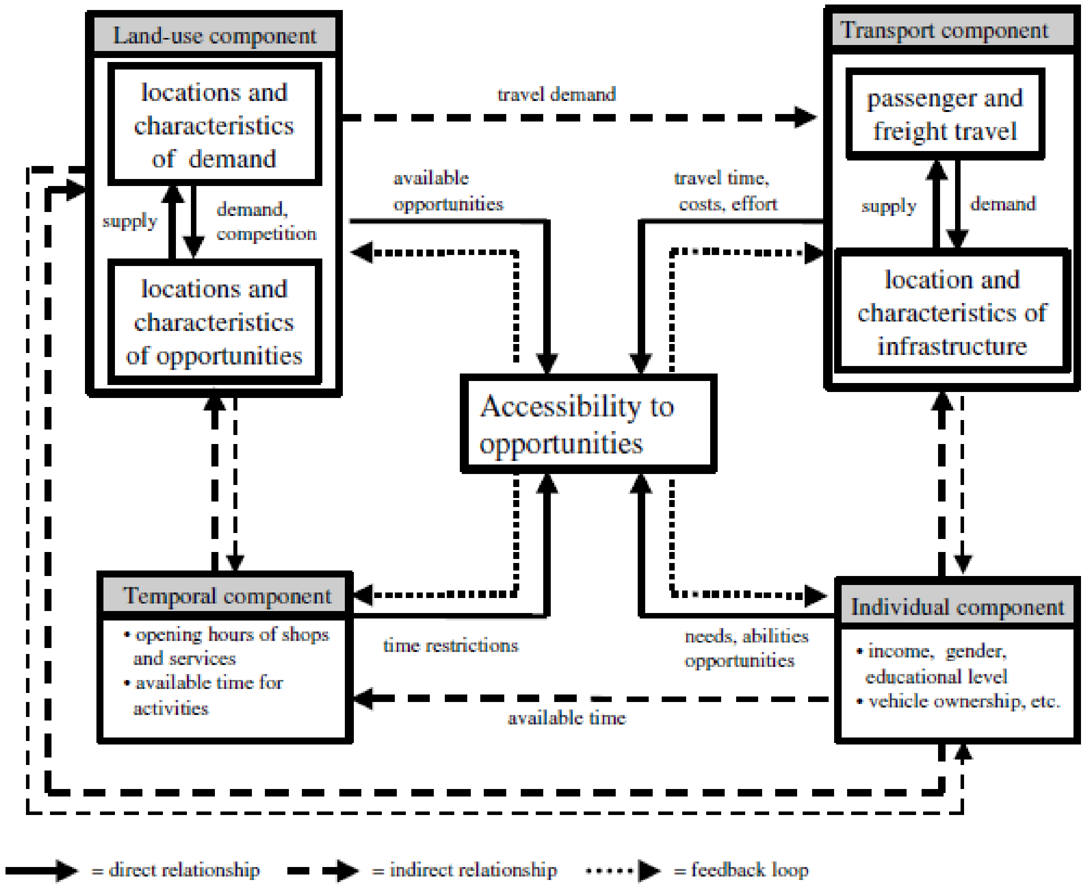
Characteristic	Variable	Examples of measures of variables
Accessibility characteristics (Three common metrics of accessibility include cumulative opportunity measures, gravity-based accessibility measures and utility-based accessibility metrics)*	Transport connectivity to region	• Type and frequency of services available
	Efficiency and ease of inter-modal connections	• Number of inter-modal connections available
	Transport connectivity to employment	• Type and frequency of services available
	Transport connectivity to activities	• Type and frequency of services available
Quality of transit service	Level of service	• Frequency and hours of service • Number of access locations • Rates of usage • Fare structure • Infrastructure conditions
Environmental and social stress factors	Existing noise levels	• Proximity to major roadways
	Existing air pollution levels	• Proximity to major roadways and polluting industries
	Safety	• Number of injuries and deaths • Level of traffic risk • Number of life years lost

Source: Adapted from Transport and Infrastructure Council (2016, p. 14), Cambridge Systematics et al. (2002) and Martens et al. (2019).

* For further discussion about the measures of accessibility, see Deboosere and El-Geneidy (2018).

Geurs and van Wee (2004) reviewed accessibility measures used in land use and transport evaluation. They present theoretical criteria for accessibility measurement consisting of four components whereby ideally an accessibility measure should account for all four components. These include a land-use, transportation, temporal and an individual component. Figure 2.4 shows the relationships and characteristics of these components. Geurs and van Wee concluded that an ideal accessibility measure would include feedback mechanisms among land-use, travel demand and accessibility requiring land-use, and transport interaction modelling.

Figure 2.4 Relationships between components of accessibility



Source: Reprinted from Geurs & van Wee (2004, p. 3)

Geurs and van Wee (2004) identified four commonly used measures of accessibility in the literature, which can be broadly classified as infrastructure, location, person and utility-based measures.

Infrastructure-based measures are based on the functioning of the transport systems, such as congestion, travel times and operating speed, and have been used in assessments by Linneker and Spence (1992), AVV (2000) and the UK Department of the Environment, Transport and the Regions (2000). As noted by Geurs and van Wee (2004), while these measures of accessibility are useful, they fail to account for the land-use component of accessibility, or, in other words, the activities an individual would participate in when they reach a destination.

Location-based accessibility measures include assessments undertaken by Golub and Martens (2014), who used a cumulative-opportunity accessibility measure in their study of modal equity. Their accessibility measure is based on the ratio of essential destinations (including jobs, jobs of certain types, schools and medical facilities) reachable within certain times by transit and automobile. An explicit minimum ratio is a benchmark for 'access poverty' and compares the distribution of accessibility between different minority and income levels as a measure of transport equity.

In our readings, location-based accessibility measures are the most commonly used method of determining transport accessibility (Brussel et al., 2019; Kelobonye et al., 2019). Kaplan et al. (2014) used an alternative location-based accessibility measure involving the assessment of connectivity based on the potential accessibility across all zones within a study area (as opposed to areas reachable given a set travel time). In the study by Kaplan et al. (2014), accessibility is measured based on the transit connectivity weighted by total transit travel time (including transfers) and the perceived discomfort of passengers for different time components.

Person-based measures require detailed information on individuals and their relationship with space and activities (Fransen & Farber, 2019). These are often based on origin–destination travel matrices for travel times (or travel cost) to destinations. Alternatively, activity diaries are used to determine the daily travels of individuals over the course of an entire day.

Utility-based measures, particularly the logsum measure advocated by de Jong et al. (2007), are used to calculate changes in consumer surplus for transport appraisals. The methodology measures the expected utility from a choice from a set of alternatives representing traveller accessibility. From a technical perspective, the logsum is the log of the denominator of a multinomial logit model (Nahmias-Biran & Shiftan, 2016). Logsums (or expected utility) for each individual can be calculated and aggregated over groups for use in disaggregate analysis in transport equity assessments. Logsum has seen general use (that is, specifically for the purpose of transport equity evaluation) in transport project appraisals overseas (de Jong et al., 2003; Freedman et al., 1981; Gupta et al., 2006).

In van Wee's (2016) review of the logsum as an accessibility indicator, he noted its usefulness in its alignment with the CBA framework due to the inclusion of utility of choice option, its capability to deal with changes in spatial distributions of origins and destinations and the variety of choice options measured by multiple attributes of alternatives that can be included. The limitations are that the value of having multiple options is ignored, expected utility may differ from experienced utility, the use of willingness to pay to calculate utility is disputed, and it can be difficult to explain logsum as an accessibility measure. Geurs and van Wee (2004) also noted that the logsum measure fails to include the spatial–temporal constraints experienced by individuals.

2.2.7 Overseas experience

Our review of the overseas experience shows significant differences between the recommended approaches for distributional analysis in transport CBA appraisals. We suspect the reason for differences across guidelines is the agencies' different procedures for decision making using the outcomes of the appraisals.

2.2.7.1 Australian Transport Assessment and Planning Guidelines

The Australian Transport Assessment and Planning Guidelines advise accounting for distributional effects: 'Equity assessments can be a critical input in the selection of the preferred option for a transport initiative. In some cases, it may be a key factor in whether an initiative actually proceeds. An equity assessment can complement the cost–benefit analysis of a transport initiative (Transport and Infrastructure Council, 2016, p. 6).

This guideline suggests that, to minimise the risks of equity issues creating a barrier for an initiative proceeding, it is important to account for equity considerations from the early stages of option development.

Transport interventions can cause equity effects in the primary market. The Transport and Infrastructure Council (2016) notes that the distributional effects of transport initiatives typically arise from three sources:

- Transport benefits, including accessibility and mobility,[30] greater transport choice, reduced time travel or safety (reduced risk of crashes)
- Transport costs, including who pays for the services (through user fees, taxes and so on) and how the costs paid compare to the benefits received

[30] Traditional transport CBAs aim to improve mobility. In our report, we discuss the importance of aiming to improve accessibility of different socioeconomic groups.

- Externalities, including air and noise pollution, vibration, loss of visual amenity and open space, community severance, related property price effects and quality of life issues.

The origins, destinations and composition of people or freight benefiting from a transport improvement could be important indicators of how benefits are distributed. Transport initiatives create various effects. These include changes in accessibility, mobility, travel time and safety, or environmental changes. Each of these, as well as their combined effects, will have distributional (equity) impacts on different population groups.

Under the *Australian Transport Assessment and Planning Guidelines for T5 Distributional (Equity) Effects*, it is acknowledged that no harmonised methodology exists in assessing equity in Australia or overseas (Transport and Infrastructure Council, 2016). Instead, the guidelines provide guiding principles, tools and techniques for undertaking equity evaluation. The procedure for considering equity analysis is provided as a five-step process with community participation involved throughout. An overview of the steps is given below:

1. Scoping – identifying communities of interest
2. Profiling – developing a profile of individuals or groups identified in the scoping phase
3. Impact characterisation – identifying impacts under different assumptions or development options of scenarios
4. Analysis – evidence-based assessment of equity effects
5. Response – considering the alternative choices for mitigation.

The guidelines provide an overview of the types of equity, including: horizontal, vertical, spatial or territorial and inter-generational (see section 2.2.4.2 for more details). As noted, although no harmonised methodology exists in assessing equity, various potential assessment types are provided, including indexes (such as the Gini index), equity weights, social impact assessment, stated preference surveys, spatially based analysis and micro-simulation (see section 2.3 for more details).

2.2.7.2 United Kingdom Department for Transport

The UK's guideline for CBA (the Green Book), which is applied generally and not just for transport, recommends a weighting method for policy that has significant distributional effects, but only where confidence is high about the groups that will be affected (HM Treasury, 2020). The Department for Transport (DfT) (2020a) provides CBA guidelines for transport appraisals in the UK, by using the Green Book guidelines. The DfT (2020a) identified several domains in the assessment of distribution impacts, including user benefits, noise, air quality, accidents, security, severance, accessibility and personal affordability. The first step in the DfT (2020b) appraisal process is screening, which identifies the likely effects for each domain of impacts. In a second stage (assessment), the analysis needs to confirm the area impacts by the transport intervention, identify the social groups in the impact area, and identify the amenities in the impact area. In the last stage, the analysis needs to measure the impacts within a worksheet (DfT, 2020b, p. 4).

Each domain is assessed on its respective impacts on individuals. This includes transport users and people living and travelling in areas that will be affected by the intervention. To integrate distributional costs into the wider UK transport assessment guidance (TAG), evaluators first identify broad impact areas of the transport intervention and then investigate the spatial impacts in more detail.[31] Using the spatial distribution of impacts, the impacts are distributed by affected social groups in the area. Appraisals of impacts are conducted at a high level based on the distribution of beneficial and adverse effects on population groups relative to the total population. Table 2.5 shows DfT's identification of people groups (rows of the table) for each impact area (columns of the table). Accordingly, while the analysis needs to consider income distribution for user benefit

[31] It is necessary to confirm the overall geographical area experiencing impacts and consider which specific areas are relevant to the distribution effect appraisal.

impacts, impacts on young adults need to be considered for accidents. Atkins (2019) provides a distributional impact appraisal of the Stubbington Bypass scheme using DfT's guidance.

Table 2.5 Scope of socio-demographic analysis for distributional impacts as defined by DfT (2020a)

Social group	User benefits	Air quality	Accidents	Security	Severance	Accessibility	Affordability	Noise
Income distribution	✓	✓					✓	✓
Children: aged under 16 years		✓	✓	✓	✓	✓		✓
Young adults: aged 16 to 24 years			✓			✓		
Older people: aged 70-plus years			✓	✓	✓	✓		
Population with a disability				✓	✓	✓		
Population of black minority ethnic origin				✓		✓		
Households without access to a car					✓	✓		
Households with dependant children						✓		

Source: Adapted from DfT (2020a, p. 6)

Much of the research published internationally focuses on differential levels of accessibility, particularly on employment and for lower-income groups. Along with the groups listed in Table 2.5, other transport impacts that have been assessed include geographic location, household structure (for example, children and/or single parents), household tenure, deprivation, car ownership, disability, faith, economic activity, educational qualifications, being in receipt of state benefits, and indices of multiple deprivation (Jones & Lucas, 2012; Lucas, 2012; Lucas & Jones, 2012).

2.2.7.3 United Kingdom Government – levelling up approach

In February 2022, the UK Government published its paper *Levelling Up the United Kingdom*, in which 'levelling up' is a moral, social and economic programme that focuses on spreading opportunity more equally across the UK. Accordingly, transport infrastructure is identified as an important (physical) capital that reduces distances between places and provides increased market access. The paper highlights that:

> *[…] not everyone shares equally in the UK's success. While talent is spread equally across our country, opportunity is not. Levelling up is a mission to challenge, and change, that unfairness. Levelling up means giving everyone the opportunity to flourish. It means people everywhere living longer and more fulfilling lives, and benefitting from sustained rises in living standards and well-being. This requires us to end the geographical inequality which is such a striking feature of the UK.* (HM Government, 2022, p. xii)

To level up, the UK Government suggests it is necessary to:

1. Boost productivity, pay, jobs and living standards by growing the private sector, especially in those places where they are lagging
2. Spread opportunities and improve public services, especially in those places where they are weakest
3. Restore a sense of community, local pride and belonging, especially in those places where they have been lost
4. Empower local leaders and communities, especially in those places lacking local agency.

The paper, in particular, outlines challenges facing the UK's transport sector, including the *disparity in transport infrastructure between cities*. It highlights that nearly 30 percent of all public transport infrastructure spending is in London, because investment tends to flow in the areas where infrastructure is under greater strain, rather than less extensive. Another challenge for the transport sector is the *poor local transport* infrastructure. The UK's core cities (Belfast, Birmingham, Bristol, Cardiff, Glasgow, Leeds, Liverpool, Manchester, Newcastle, Nottingham and Sheffield) rank lower in productivity than other second-tier cities in other countries when gross value added per worker is considered, partly due to poor local transport infrastructure. For example, the Centre for Cities (2021) found, in Europe overall, around 67 percent of people can get to their local city centre in 30 minutes using public transport, compared with only 40 percent in Britain.

2.2.7.4 European approach

Bristow and Nellthorp's (2000) review of transport project appraisal in the European Union notes that, while equity is often referred to in transport policies, its treatment in transport investment appraisal 'lags behind these good intentions' (p. 7). The authors note the German evaluation is both detailed and explicit in its treatment of effects on different regions within the country, citing additional weight was given to employment impacts in the former East German lände and other regions in the country, in recognition of their economic problems. Bristow and Nellthorp (2000) also note that distributional effects are assessed and presented as part of a supplementary study alongside cost–benefit results and other findings presented to decision-makers. In many other European Union countries, little evidence is available that equity and distributional effects are given a significant role in project appraisal outputs.

2.2.7.5 North American approach

In the review by Manaugh et al. (2015) of social equity related goals of North American transportation plans, the authors conclude the objectives of social equity are, in most cases, unclear. The results of their review also suggest that studies have not used appropriate measures for assessment, with meaningful disaggregation of impacts.

2.3 Measures of equity

2.3.1 Summary

This section considers different methods for quantifying equity in transport. The most common measures of equity are the equity indices used together with spatial analysis. In New Zealand, the most common index of equity is the New Zealand Deprivation Index (NZDEP), which has also been measured spatially. Along with the indices, stated preferences, methods and microsimulation techniques provide a robust technical framework for assessing equity impacts.

2.3.2 Introduction

Researchers and practitioners are working to develop better practical methods for social equity analysis. This can be challenging, because equity can be defined in various ways, different impacts need to be considered, and people can be grouped in several ways for equity analysis (Litman, 2022). A particular policy may seem equitable if measured in one way but inequitable if measured in another (Lucas et al., 2019; Marjanovic et al., 2009). Nunns et al. (2019) note that assessing equity impacts based on 'winners' and 'losers' is a fallacy implying that the status quo is fair, which may also be inequitable under different definitions.

To measure equity, it is necessary to understand who will be affected by a transport initiative and to what extent. It is necessary to define the type of equity, identify the groups affected by the initiatives, and find the measures and methods of measurement for the type of equity considered. We present the types of equity in section 2.2.4. The measurement of the identification of population groups and measures are inter-related, as discussed in this section.

Several qualitative and quantitative techniques are available for assessing equity impacts. The top-down techniques are used for disaggregating a sum of benefits estimated based on different methodologies across different socioeconomic groups using distributional weights. The bottom-up techniques, on the other hand, estimate the benefits at a disaggregated level and then sum them to estimate the total impact.

Measurement of equity outcomes is a sensitive task that needs to be consistent with the targeted equity concept. Transportation equity is difficult to evaluate because defining and measuring impacts and characterising people can be done in various ways, as shown in Table 2.6. Litman (2022) suggests that an evaluation accounting for distributional effects must consider various perspectives, impacts and metrics.

Table 2.6 Equity evaluation variables

Types of Equity	Impacts	Measurement	Groups
Horizontal (Fairness) Equal treatment of equals Proportional benefits and costs "Get what you pay for and pay for what you get"	**Facilities and Services** Facility planning and design Public funding and subsidies Public involvement	**Levels of Impacts** Inputs (funding, road space, level of support) Output (mobility) Ultimate outcomes (destinations accessed, user costs, crash casualties, etc.)	**Demographics** Age and household type Race and ethnic groups income and poverty rates Ability and disabilities Licensed drivers
Vertical with-respect-to need and ability Universal design Special mobility services Disabled parking Service quality for non-drivers	**User benefits and costs** Service quality Universal design Taxes, fees and fares	**Per capita** Per adult Per commuter or peak-period travel Per household	**Location** Jurisdictions Neighbourhood and street Urban/suburban/rural
Vertical with-respect-to income and social class Affordability Impacts on low-income communities Fare structures and discounts Service quality in lower-income communities Industry employment	**External impacts** Congestion and barrier effect Crash risk Pollution Hazardous material and waste Community livability	**Unit of travel** Per vehicle-mile/km Per passenger-mile/km Per trip Per commute or peak-period trip	**Mode** Pedestrians and cyclists Motorists and motorcyclists Public transit users
	Economic impacts Economic opportunities Business activity and employment	**Financial** Per dollar Subsidies Cost recovery	**Industries** Transportation producers Shippers Employees
	Regulation and Enforcement Traffic regulation Regulations and enforcement Regulation of special risks		**Trip type** Emergency Commutes Commercial/freight Recreation/tourist

Source: Adapted from Litman (2022, p. 4)

2.3.3 Methods and tools for quantification

With some differences across the methods available for quantification of equity effects, the steps needed for quantification are similar across available international guidelines. The Transport and Infrastructure Council (2016, p. 8) recognised 'there is no harmonised methodology for undertaking equity assessments in Australia or overseas'. Analysis is not needed for all projects and depends on jurisdiction, scope and type of initiatives. Scoping of a distributional and/or equity analysis starts with identifying communities of interest and developing a profile of groups and individuals affected. Behbahani et al. (2019) propose a general framework for including equity in infrastructure investment studies comprising three steps: determining the distributable benefits and costs; identifying and classifying the target groups; and selecting the equity approach.

In this chapter, we refer to the most common techniques and tools for estimating distributional effects and describe the measurement and examples of applications.

2.3.4 Methods for quantifying equity

2.3.4.1 Social impact assessment method

Social impacts are the likely consequences for individuals or a community of implementing a particular course of action. Social impact assessment (SIA) is the most common technique for identifying social impacts of transport initiatives on the community. An SIA includes both social (equity) impact assessment and cumulative impact assessment statements.

Social (equity) impact assessment statements consider the winners and losers of an investment initiative. For an SIA, specified (winner and loser) population subgroups would be identified. Then the outcomes of the initiative would be assessed for each population subgroup.

Vanclay (2003) identified social impacts as changes to one or more factors, as shown in Table 2.7. He also lists of the core values, guiding principles and guidelines to SIA. Vanclay suggests (2003, p. 7) that social and distributional impacts are closely related: 'Awareness of the differential distribution of impacts among different groups in society, and particularly the impact burden experienced by vulnerable groups in the community should always be of prime concern'. Hence, distributional analysis is part of SIA.

Table 2.7 Factors of change contributing to social impacts

Factor	Description
People's way of life	How they live, work, play and interact with one another on a day-to-day basis
Culture	Shared beliefs, customs, values and language and dialect
Community	Cohesion, stability, character, services and facilities
Political systems	The extent to which people are able to participate in decisions that affect their lives, the level of democratisation taking place and resources provided for this purpose
Environment	The quality of air and water people use; availability and quality of food level of hazard or risk, dust and noise they are exposed to; adequacy of sanitation, physical safety, access to and control over resources
Health and wellbeing	Physical, mental, social and spiritual wellbeing, and not merely the absence of disease or infirmity
Personal and property rights	Whether people are economically affected or experience personal disadvantage, which may include a violation of their civil liberties
Fears and aspirations	Perception of safety, fears about the future of their community, aspirations for the future and the future of their children

Source: Adapted from Transport and Infrastructure Council (2016, p. 14) and Vanclay (2003, p. 5)

Levinson (2002) provided an SIA checklist, including stratification variables (for example, population, gender or spatial extent), specific process requirements (such as the opportunity to participate in decision-making), as well as desired outcome areas (such as mobility, economic, environmental and health outcomes) for transport initiatives.

In evaluating a project, SIA places further emphasis on the outcomes for specific socioeconomic groups to improve the lives of vulnerable people. This leads to a normative output, which is consistent with Rawlsian ethics (Esteves et al., 2012). SIA and CBA are related but different analyses. Reporting distributive impacts in CBA would not completely eliminate the need to conduct an SIA, because the latter would include more contextual but not quantifiable or monetised impacts.

2.3.4.2 Cumulative impact assessment method

Cumulative impact assessment results from the incremental effect of an action when added to other past, present and reasonably foreseeable future actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over time. Given our discussion about the long-lasting impacts of transport investments on equity, an analysis of equity needs to account for the cumulative impact assessment. The Transport and Infrastructure Council (2016, p. 21) notes:

> *It is generally recognised among practitioners that specific methodologies for the assessment of indirect and cumulative impacts, particularly for predicting reasonable foreseeable impacts, are not as well established or universally accepted as those associated with direct impacts, such as traffic noise analysis or wetland delineation. Determining the most appropriate technique for assessing indirect and cumulative impacts of a specific initiative should include communication with the cooperating agencies and community stakeholders.*

2.3.4.3 Stated preference surveys method

Using a stated preference approach, equity analysis could derive statistical estimates of the rates of trade-off between alternatives. This could be achieved from respondents' ranking of the relative importance of key attributes after accounting for the budget constraint.[32]

Various issues with survey data collection may affect the accuracy of the stated preference method. However, a well-implemented survey accompanied with robust (econometric) methods could provide useful information that cannot be inferred from other methods (Transport and Infrastructure Council, 2016).

2.3.5 Tools for quantifying equity

2.3.5.1 Equity indices

A range of studies provide indices to measure equity (or inequity) across different socioeconomic groups. Many measures exist for quantifying vertical equity. These include the Atkinson index, Gini coefficient,[33] mean log deviation (LDEV) and Theil index, which measure the distribution of wealth in a population, typically reported as a value from 0 (which expresses perfect equality) up to 1.0 (which represents maximum inequality).

Radbone (1994) criticises the use of household income for estimating travel demand as an explanatory factor, arguing that, given the differences in household composition and size, it is not a good indicator of

[32] This method is used for the upcoming Waka Kotahi report (in press) to provide new values for the value of a statistical life, travel time and reliability, based on choice modelling using survey design.

[33] The Gini index is the best-known and most-used equity index. It provides information about income inequality across society. The usefulness of the Gini index for assessing transport initiatives is discussed in the following paragraphs.

financial wellbeing. Loeis and Richardson (1997) suggest using an equivalence scale to create a standardised measure of a person's economic capacity. They developed a 'welfare index' that aggregated related individuals in the same households into 'income units' and accounted for socio-demographic factors including income, employment status, age of dependants, household costs and household size.

Rietveld (2003) suggests equivalence scales as a means of accounting for consideration of welfare position of households, rather than incomes. Rietveld also suggests an integrated efficiency-equity approach that uses income corrected for quality of life along with an inequality indicator.

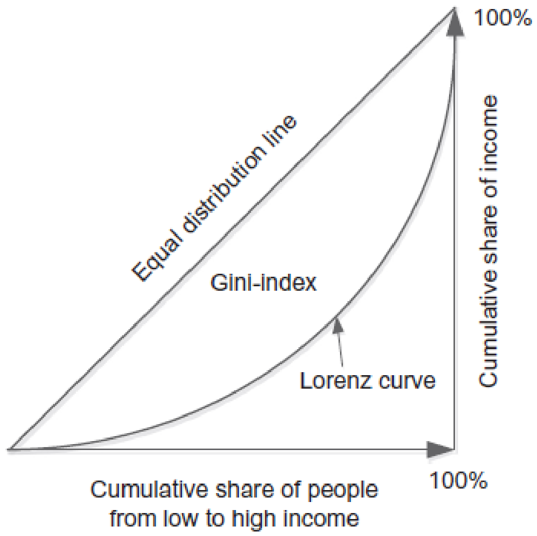
In New Zealand, a typical measure used for capturing the distributional outcomes of transport investments is the NZDEP, which is an area-based measure of socioeconomic deprivation (Atkinson et al., 2019). NZDEP has been used in a variety of studies concerned with distributional effects across New Zealand communities (Curl et al., 2020, p. 25). Studies use both the index and score measures of deprivation. The distribution and use of the score and index measures have important differences. Torshizian (2017) provides further details on the advantages and disadvantages of using each measure. The New Zealand Index of Multiple Deprivation (NZIMD) is another area-based deprivation measure; it differs from NZDEP in that it consists of seven domains of deprivation, as opposed to a single index and score. The NZIMD includes indices related to the domains of employment, income, crime, housing, health, education and access (Exeter et al., 2017).

Evaluations of transport equity often rely on a mix of statistical methods, allowing for the measurement of the level of (in)equality of distributions in transport (van Wee & Mouter, 2021). Methods range from simple statistical measures, such as changes in mean, range and variance, to more complex statistical distribution measures including the Thiel, Gini, Atkinson and Kolm indexes. The differences between these measures reflect different perceptions of inequality (Ramjerdi, 2006; van Wee & Geurs, 2011; van Wee & Mouter, 2021).

The most commonly used measures of (in)equality for transport equity evaluation are the **Gini coefficient** and **Lorenz curve**, likely due to their interpretability and ease of communication (often used together with descriptive statistics). Generally used for comparing income distributions, the Lorenz curve and Gini coefficient can be adapted for evaluating any other unit, such as measures of transport accessibility (travel times, travel cost, accessibility indexes), safety (traffic fatalities and injuries) and the environment (carbon dioxide emissions) (van Wee & Mouter, 2021).

The Lorenz curve graphically shows the cumulative distribution of people (or regions or another unit of comparison) (from 0 to 100 percent), ordered from a low to high value of an indicator, such as income, on the x axis, and the value of that indicator for these groups of people on the y axis (van Wee & Geurs, 2011, p. 9). The Lorenz curve is a graphical representation of equality and the Gini coefficient is a single value measure representing the overall extent of inequality. It is the ratio between the area between the line of equality and the Lorenz curve (Delbosc & Currie, 2011a). See Figure 2.5.

Figure 2.5 Lorenz curve and Gini coefficient



Source: Reprinted from van Wee & Mouter (2021, p. 9) adapting Silber (1999)

Delbosc and Currie (2011a) used Lorenz curves and Gini coefficients to assess public transport equity in Melbourne, Australia. They determined a public transport index based on service frequency and modal options and access-distance to public transit (Currie, 2010), and compared this (using Lorenz curves and Gini coefficients) against both population and population and employment combined. Delbosc and Currie (2011a) evaluated horizontal equity by mapping the proportion of population and employment relative to the supply of transit services. To assess vertical equity, they compared the mean and median supply of public transport per person or per household across different socioeconomic and demographic factors.

Kaplan et al. (2014) measured equity of transit provision using potential accessibility measures and Gini coefficients. They determined accessibility using weighted origin destination pairs with consideration of the additional time required when using public transport, including walking to and from stops, and transfers.

Nahmias-Biran et al. (2014) used Lorenz curves and Gini coefficients to measure the impact of fare changes to the transit system in Haifa, Israel. Vertical equity assessment was undertaken using descriptive statistics. Due to the lack of income data, assessment of horizontal equity is based on the cumulative proportion of population and their cumulative change in fare.

Rofé et al. (2015) evaluated changes in the public transport system in Tel Aviv–Yafo, Israel, following a bus reform in 2011. They used a combination of measures including Lorenz curves, the Gini index and the poverty line (which they reformulated to measure differences in accessibility). The authors define accessibility, in an operational sense, as the number of destinations (jobs in this case) of interest accessible within a reasonable time from using different transportation modes. This was accomplished using computational geographic information system (GIS) methods and constructing the relative level of accessibility between all origins (buildings in Tel Aviv–Yafo) and destinations (jobs). Given the study relates to improvements in public transport, the authors constructed a relative accessibility index by taking the ratio of the number of destinations accessible using public transport relative to the number of destinations accessible using a car given a set trip time.

Lorenz curves and the Gini index were adopted to evaluate the inequality of relative accessibility between the old and new bus network. In their evaluation of vertical equity, Rofé et al. (2015) used both a transport needs index, based on methods by Currie (2004, 2010), and incomes. Comparing the relative accessibility index against a public transport needs index, Rofé et al. (2015) found no connection exists between public transport services and the need for it, suggesting the city does not serve the people most dependent on transit services particularly well. Furthermore, the authors assessed accessibility poverty by adopting the poverty line methodology accounting for both intensity and size. A pragmatic approach to setting the threshold for accessibility poverty was undertaken by choosing the arbitrary values of 20 percent and 50 percent average car-based accessibility in Tel Aviv–Yafo.

2.3.5.2 Equity weights

These weights provide a method of explicitly incorporating concepts of fairness into economic analysis. As discussed in section 2.1.2, the use of weights is associated with economic inefficiencies. Equity weights show the level that a society is willing to sacrifice for efficiency in pursuit of fairness. A larger equity weight indicates a society is willing to decrease efficiency more to increase fairness. The weights could be either representative of the view of the (sample) population or of decision-makers and analysts.

Equity weights lead to a further emphasis on the benefits for one group compared with another. For example, if an initiative leads to benefits to population groups A and B, the net benefits would be weighted by W_a and W_b for population groups A and B, respectively, and the net benefit of the initiative is equal to the sum of the net benefits to population group A (N_a) and net benefits to population group B (N_b), which is equal to: $W_aN_a+W_bN_b$. One way of defining weights is by considering the marginal utility of income for the high (h) and low (l) income groups.

The use of equity weights is only recommended by the UK’s Green Book:

> *Distributional weights can be used as part of the distributional analysis where there is understood to be a social value that differs from simple additionality due to who gains or loses. To account for the uncertainties, sensitivity analysis is recommended and it may be useful to estimate switching values i.e. the distributional weights required to change the preferred option. This provides an estimate of the certainty of the results based on the weights used.* (HM Treasury, 2020, p. 54)

However, the Green Book also acknowledges that:

> *In practice the use of distributional weighting is challenging. This is due to uncertainty in the assumptions relating to the groups between whom redistribution is measured and uncertainty in estimation of distributional weights.*[34] (HM Treasury, 2020, p. 54)

Because equity weights are considered a method of mitigation, they are discussed further in section 2.4.4.

2.3.5.3 Spatially based analysis

Spatially based analysis is commonly used in transport appraisals because the transport initiative investment occurs on a spatial scale and its impacts should be measured on a spatial scale. The analysis is based on measures of accessibility, referred to in section 2.2.6, and indices of equity, as described in section 2.3.5.1, identified at a spatial scale. The analysis is commonly undertaken with GIS technology.

After identifying distributional impacts over a geographical scale, relevant socioeconomic characteristics need to be transposed onto the geographical representation of the impact.

The accuracy of the spatially based analysis depends on the use of appropriate spatial scale. The Transport and Infrastructure Council (2016, p. 22) notes that:

> *Due to the aggregate nature of common data sources on population characteristics (such as the census), Statistical Local Area or Local Government Area population characteristics are generally*

[34] This suggests determining ‘switching values’ for equity weights could involve more degrees of freedom than one would like.

used as a proxy for specific groups being examined. For example, if concern is expressed over impacts on low income or minority populations, the impacts are measured for neighbourhoods that exceed a certain percentage of those population groups, rather than for specific minority persons or households. This provides the decision-maker with a representation of the distributional effects of initiatives on the communities of interest, i.e. the 'winners' and 'losers'.

Also, as noted in section 2.2.3.1, the choice of location and spatial dependence of features of the living environment increase the complication of spatial analysis (Torshizian & Grimes, 2014).

El-Geneidy et al. (2016) used a combined time cost and transit fare indictor, and the cumulative opportunities of job accessibility at different travel times and costs, as a measure of transit accessibility. They disaggregated their results using a social disadvantage indicator to analyse the vertical equity of transit services in Montreal, Canada. As part of their analysis, the authors also determined travel times between census tracks using GIS methods (OpenTripPlanner and General Transit Feed Specification data).

Qi et al. (2020) combined the use of a public transport needs indicator based on works by Currie (2004, 2010) and a relative modal accessibility measure, to access the quality and equity of public transport services across socioeconomic groups in Sydney, Australia.

Raux and Souche (2004) used a strategic travel demand model and its outputs to assess horizontal, vertical and spatial equity applied to a theoretical case study for urban road pricing in Lyon, France.[35] They used an index based on average trip duration and price to evaluate *spatial equity* based on changes in *accessibility* to employment zones. To assess *horizontal equity*, they determined the total change in value of time per travel mode, assuming all individuals have the same average value of time. *Vertical equity* was assessed using the change in travel time and travel cost across different income groups.

Pereira et al. (2018) used spatial regression methods to compare the distributional changes in transit accessibility to jobs and high schools in Rio de Janeiro, Brazil, in 2014 and 2017. First converting spatial demographic variables into hexagon units (as an uniform spatial unit), the authors regressed the log ratio of schools and jobs to the log variables of income, population density, job density and elevation for aggregate hexagonal spatial units to control for spatial autocorrelation. The change in log income is used as a single measure of change in accessibility. Pereira et al. also used data visualisation methods by plotting 2017 accessibility ratios against those of 2014, coloured by income decile and scaled using population counts. They used bivariate thematic maps to spatially illustrate income versus accessibility.

In their assessment of transport equity across environmental justice communities, Rowangould et al. (2016) measured accessibility (based on travel time to jobs) across different community groups. The study is notable because it focuses on the technical measure in classifying community groups. Rowangould et al. highlighted threshold approaches where the spatial unit comprises the proportion of peoples greater than the set ratio, or alternatively greater than the country's population average, a standard deviation greater than the country average, or the proportion of vehicle ownership. A community-based approach whereby community members identify areas for themselves is also used. Lastly, they also evaluated population weights approximating population contiguously across space.

2.3.5.4 Micro-simulation techniques

Micro-simulation is a recent technique used for modelling distributional and equity issues by focusing on personal attributes across individuals in the population. In the analysis of distributional effects, micro-simulation techniques forecast travel behaviour of different socioeconomic groups by modelling a set of

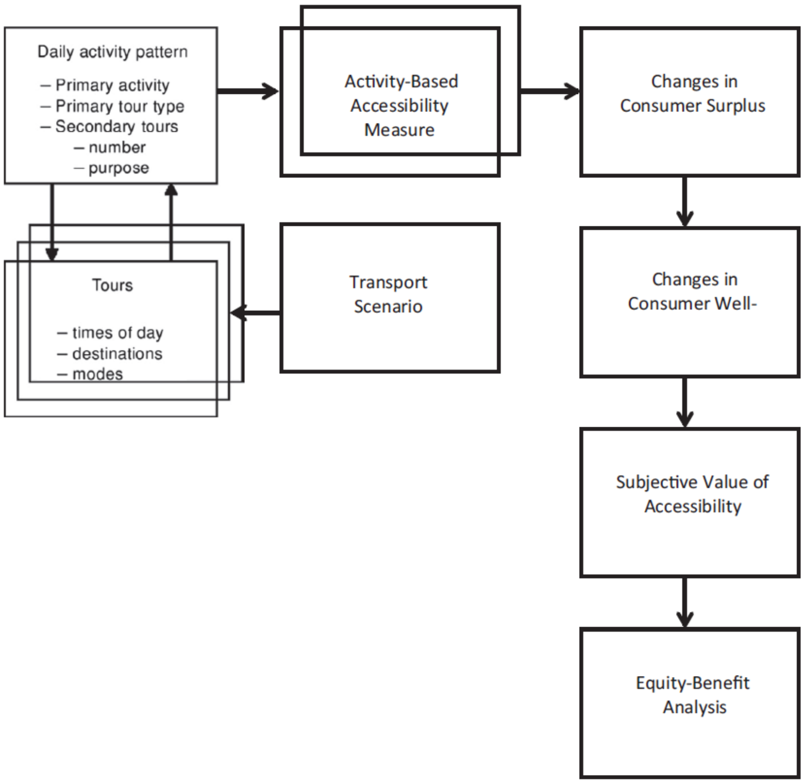
[35] Raux and Souche (2004) simulated travel demand patterns using a range of sub-models to account for factors including, socio-demographic, economic, model choice, peak period travel, origin–destinations and traffic.

actual or ‘synthetic’ individuals or households that represent the population as the basic unit of analysis, rather than dealing with population averages by postcode or statistical region. A ‘synthetic’ sample comprises a hypothetical set of people or households with characteristics that, as a whole, match the overall population. Results are aggregated only after the individual or household analyses are completed, allowing the user greater flexibility in specifying output categories. This is commonly referred to as sample enumeration or discrete choice analysis. Sample enumeration relies on the modelling of behaviour for a representative sample of the population generally derived from a regional home interview survey or stated preference survey.

As highlighted by the Transport and Infrastructure Council (2016), the benefit of the micro-simulation modelling approach for analysing distribution of impacts is that travel patterns, and therefore the travel benefits of transportation improvements, can be tracked across any population characteristic included in the sample of persons modelled. An example of a micro-simulation programme is the Safe Transport for Every Pedestrian, which has been used by the US Department of Transport and the US Environmental Protection Authority to analyse the travel impacts of pricing scenarios by income groups, with the intention of reducing transport emissions.

Nahmias-Biran and Shiftan (2016) presented a theoretical framework in evaluating the subjective value of accessibility, assuming a linear relationship between subjective wellbeing and income. They used activity-based modelling to determine an individual’s daily travel behaviour (or activity schedule) and activity-based accessibility measures to determine their maximum utility across all possible activity schedules. This was then converted to subjective wellbeing using the marginal utility of income, providing a comparable subjective value of accessibility. Figure 2.6 shows the theoretical framework that Nahmias-Biran and Shiftan (2016) used in their assessment.

Figure 2.6 Subjective value of accessibility calculation process



Source: Reprinted from Nahmias-Biran & Shiftan (2016, p. 679)

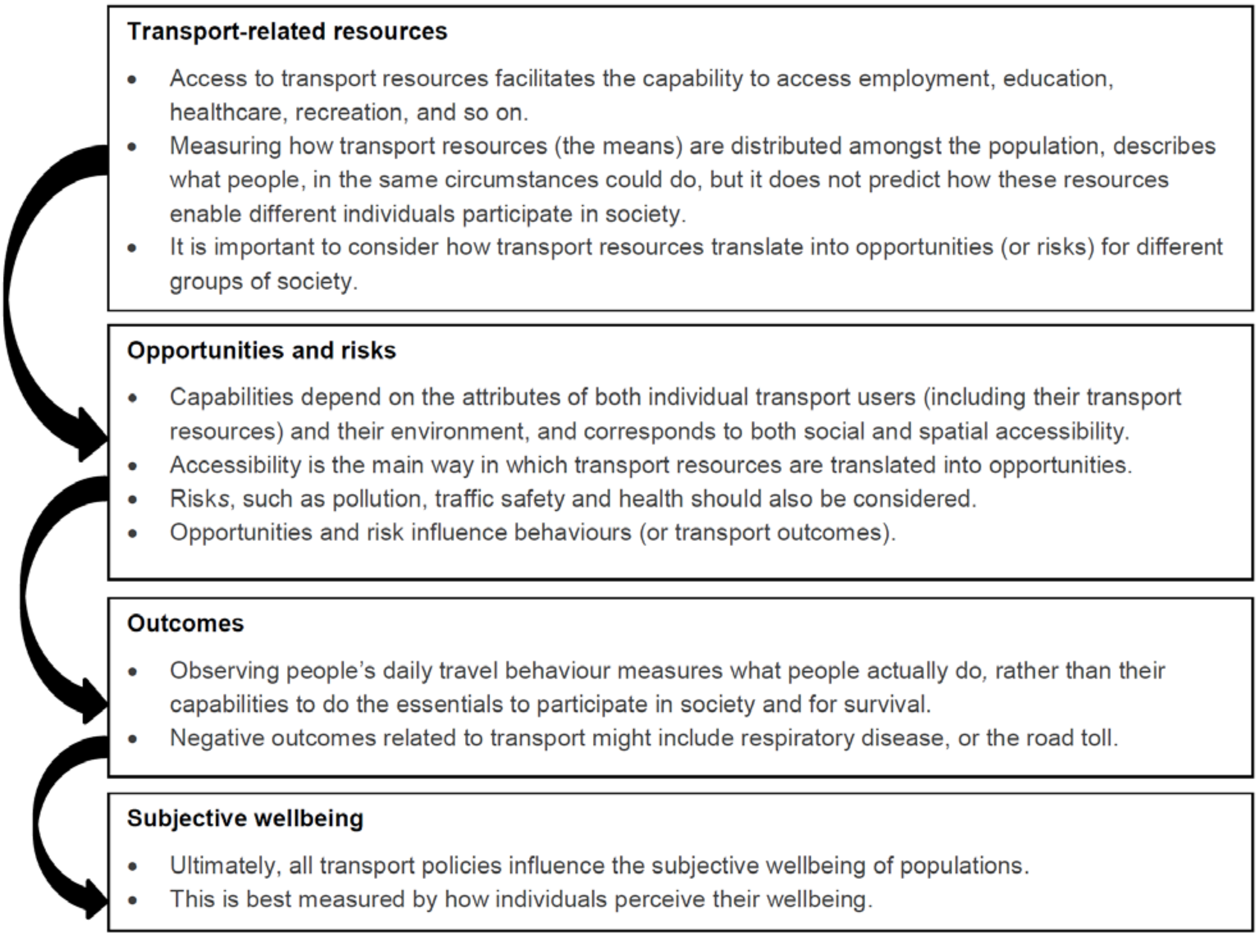
Foth et al. (2013) used paired and unpaired t-tests to compare a social indicator against accessibility and transit travel time to jobs (at a granular disaggregated geographic level). They used a social indicator score based on median household income, labour force status, immigration history and housing rents. Accessibility to jobs was based on gravity-based modelling, while transit time was based on origin–destination pairs.

Nahmias-Biran et al. (2017) presented two transport equality evaluation methods: a utilitarian approach and the capability framework. First, using the utilitarian theory of justice, they adopted different coefficients for each mode type (bus and car) for each income group, providing outputs suitable for a traditional CBA. Following the capabilities approach, Nahmias-Biran et al. (2017) presented a spider diagram showing the level of accessibility to each destination by income group. They chose an arbitrary level of sufficiency to show how these diagrams could be used in the evaluation process using a minimum sufficiency distribution approach.

2.3.6 Modelling of outcomes beyond transport sector

Transport can cause equity effects in the secondary markets. This could be explained through a conceptual revealed and unrevealed preferences lens. Figure 2.7 shows how transport markets can track through to wider society (Curl et al., 2020).

Figure 2.7 Transport-related resources, opportunities and risks, outcomes and subjective wellbeing



Source: Reprinted from Ministry of Transport (unpublished), as cited in Curl et al. (2020, p. 24)

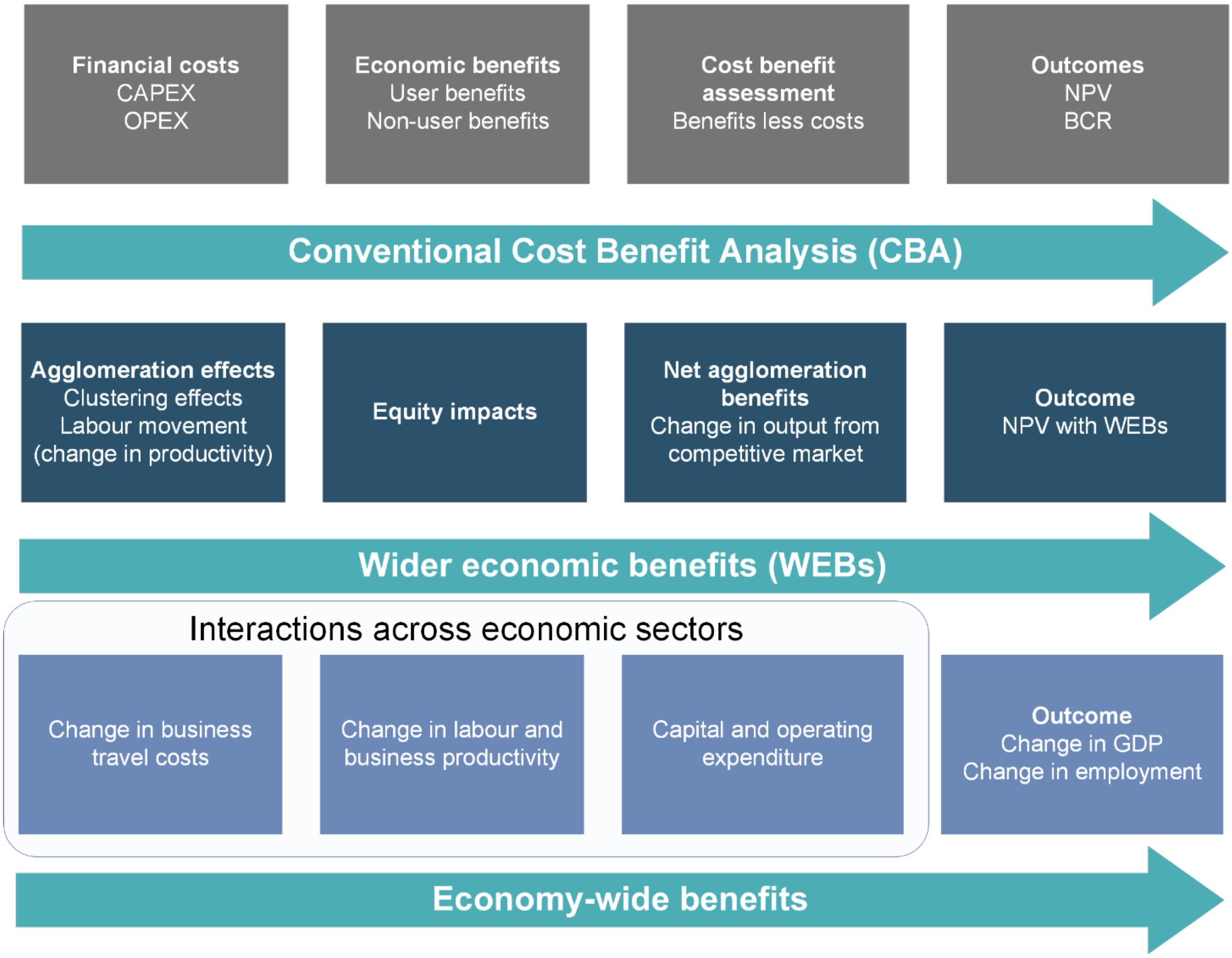
Another approach is the range of equity impacts resulting from transport interventions, such as the following:

1. The impacts identified in traditional social and distributional analysis: Various studies have focused on measuring and classifying impacts on different demographic groups. The modelling approach for this framework is usually a bottom-up approach, identifying the social, economic and environmental effects (of transport initiatives) on different communities.
2. The wider economic impacts and market failures that affect particularly disadvantaged groups: This category covers any outcomes beyond those that evaluators traditionally capture, and accounts for gains from agglomeration. Displacing employment from one place to another to improve economic outcomes in a low-performing region is associated with significant distributional effects. For further discussion about wider economic impacts in transport appraisals, see Kernohan and Rognlien (2011).
3. The economy-wide impacts: Along with impacts captured in a traditional analysis of distributional effects, a wider range of outcomes occur from interactions among businesses, households and the government. These are usually measured through a mathematical modelling framework, such as a land use transport interaction model or computational general equilibrium model, and then applying distributional weights based off a marginal utility of income (that is, a top-down modelling approach).

Transport can address existing disadvantages. Research into the above channels will reveal that transport interventions can have equity effects. This leads to two policy choices: look for ways to mitigate the disadvantage caused by the transport intervention and/or look for ways to use transport interventions to offset disadvantage caused by non-transport factors. We present the conventional CBA, wider economic benefits and economy-wide benefits in Figure 2.8.

We discuss impacts in secondary markets in section 3.1, steps 24b and 29, and section 4.3.7.

Figure 2.8 Conventional cost–benefit analysis, wider economic impacts and economy-wide benefits



Source: Principal Economics

Note: BCR = benefit–cost ratio; CAPEX = capital expenditure; GDP = gross domestic product; NPV = net present value; OPEX = operating expenditure.

2.4 Methods of mitigation

2.4.1 Summary

Various mitigating forms, or types of mitigation policies and measures, can be used to address adverse distributional impacts. Our literature review suggests the most common approach, amongst the studies that consider the CBA framework in their appraisals, is to address the shortcomings of CBA using multi-criteria analysis (MCA). The use of MCA for consideration of the equity effects is consistent with Waka Kotahi MCA guidelines.

2.4.2 Introduction

Mitigation has been defined as 'the act of reducing how harmful, unpleasant, or bad something is' (Cambridge University Press, 2011). This concept of harm reduction is apparent in the approach of

Waka Kotahi to the mitigation of transport effects on personal safety[36] and climate change.[37] To account for the distributional impacts of transport interventions, transport appraisals need to consider outcomes beyond reducing the harm of transport.

Transport interventions are associated with (a) inequity outcomes caused or worsened by the intervention and (b) inequity outcomes that simply exist but could be reduced using transport policy. It is important to distinguish between the two, to define the objective of the mitigation policy and/or method.

Accounting for the distributional impacts of transport interventions can go beyond reducing the harm of transport. For example, building a new highway between a small rural community and large urban centre will likely cause some services to centralise to the urban centre. This will harm those people in the rural centre who do not have access to a car. Various ways can mitigate this harm, including the provision of subsidised public transport.

However, many factors can lead people to experience a disadvantage, such as a lack of income, poor health and bigotry. Transport interventions may not necessarily have harmed these people, but they can be used to reduce their disadvantage. The discussion of theories of justice in transport provide reasons for using transport interventions to reduce disadvantage. At a practical level, it may be difficult to untangle whether disadvantage – a more general concept than harm – was the result of the transport system or other factors.

In terms of decision-making, the process should account for adverse impacts on disadvantaged socioeconomic groups, as well as reduce the effects of potential adverse effects of previous policies. Sheller (2018, p. 68) discusses this and suggests a focus on mobility justice and the power structures and decision-making processes that led to inequities in the first place:

> *I have suggested so far that we need to go beyond the current discussions of transportation justice because they are unable to capture the full multi-scalar and entangled dimensions of mobility justice as sketched above. I favor a sliding focus of attention that encompasses distributive concerns, including accessibility, but also opens the debate toward wider concepts such as deliberative, procedural, restorative and epistemic justice (see Table 1). These do not exist as a hierarchy, but as a kind of interplay in which there are interactions between narrower and wider apertures, as the focus shifts to different elements of justice within a mobile ontology.*

Figure 2.9 outlines Sheller's (2018) suggested nested approaches to justice.

Jensen and Thompson (2020) provide context on the development of the New Zealand Treasury's CBAx tool, which is a toolkit for estimating the societal value of alternative policy options. They note (p. 68) that '[…] cost-benefit analysis is often silent on the issue of distribution. To infer from this that the best alternative is the one that maximises the aggregate benefits over costs would be to take a substantive position on justice in distribution'. They suggest the issues of distributive justice should be considered alongside the results of CBA and different theories of distributive justice may be considered relevant. Accordingly, equity impacts should be provided for policy makers to decide.

[36] See www.nzta.govt.nz/safety/what-waka-kotahi-is-doing/nz-road-safety-strategy/, for further information.

[37] See www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/air-quality-climate/climate-change/mitigation/, for further information.

Figure 2.9 Nested approaches to justice

Source: Reprinted from Sheller (2018, p. 68)

The Waka Kotahi guidelines for MCA involve accounting for impacts on vulnerable social groups in MCA:

> *If an alternative or option has negative effects on particular vulnerable social groups (elderly, low income, disabled, etc.), the project team should consider whether additional measures can be introduced to avoid, remedy or mitigate this.* (Waka Kotahi, 2020, p. 11)

Therefore, the current guidelines focus on mitigating the inequity outcomes caused or worsened by a transport intervention.

The methods for capturing the equity impacts differ in their degree of freedom and robustness for incorporating inequity effects. It has been widely agreed in the literature that while CBA provides a robust framework for the assessment of transport policy options, it does not provide the flexibility required for the assessment of wider economic impacts alongside equity effects. Another issue, raised by Karjalainen and Juhola (2021), is that the qualitative and social aspects of urban transportation sustainability tend to be marginalised in assessments due to data limitation. Paying more attention to the easy-to-measure impacts (such as project costs, vehicle operating expenses and travel time savings) and less to the relatively difficult-to-measure social and environmental impacts (and short-term impacts receive more consideration than dispersed long-term impacts) biases decision-making. This is particularly so because not accounting for intangible impacts may result in the prioritisation of financial (and partly economic) objectives over social and environmental objectives. This also may bias decisions towards projects with higher benefits to wealthier people (over poorer people).

The challenge with other methodologies involves how they weigh different outcomes and criteria in the assessment. Our literature review is consistent with Shortall and Mouter's (2021, p. 265) conclusion that 'while each method [sustainability assessment, MCA, SIA and deliberative methods] may address one or more critiques of CBA, no method alone will counter all critiques, nor will any method be able to include all aspects of policy appraisal (environmental, economic, social, ethical)'. The use of sustainability assessment, weighted benefits within a CBA, and complementing CBA with MCA as methods for mitigation, are discussed below.

2.4.3 Sustainability assessment

Sustainability assessment considers various tools that provide decision-makers with an evaluation of global to local integrated nature–society systems in short- and long-term perspectives to help them determine which actions should or should not be taken in an attempt to make society sustainable (Shortall & Mouter, 2021).

Transport investments redefine the daily movement of goods and people, which affects quality of life and the environment. Sustainable urban transportation systems address social, economic and environmental issues in a balanced manner and promote access, affordability, safety, equity, efficiency and economic viability, while simultaneously minimising their emissions and other environmental impacts (Karjalainen & Juhola, 2021; OECD, 2002; Pardo et al., 2012; Rahman & van Grol, 2005; Sdoukopoulos et al., 2019; Sultana et al., 2019). We outline below the definitions available from the literature for environmental, social and economic sustainability (Henke et al., 2020).

- Environmental sustainability entails improvement in the quality of the urban environment and a reduction of emissions and energy consumption (greenhouse gas emission variation; pollutant emission variation; impact variation in other sectors).
- Social sustainability entails improvement in the quality of life and social equity (for example, easy access to transportation) and safety (for example, reduction in the frequency of accidents).
- Economic sustainability entails making mobility of people and goods more efficient and effective and ensuring the economic benefits produced by the project (for the period under survey) are greater than the costs.

Karjalainen and Juhola (2021) provide a comprehensive literature review of urban transportation sustainability assessments. They conclude there is a persisting definition deficit of sustainability. In New Zealand, this issue is partly addressed by the New Zealand Treasury's LSF, which, as discussed in section 1.3.1, considers sustainability as 'How effectively is our wealth used to generate wellbeing and things of economic value?'. Within the LSF, four capitals are defined: natural, human, social, and financial and physical. Transport infrastructure investments fit within the physical capital.

Consistent with the LSF, the Treasury's CBAx tool provides a spreadsheet for identifying the impacts of investments across the 12 LSF wellbeing domains. While the tool is a useful attempt to measure intangible impacts, the inconsistencies in target population across different agencies that have provided estimates of impacts, decrease the precision of this bottom-up benefit estimation practice. However, the CBAx tool is useful for highlighting the trade-offs associated with an intervention.

Torshizian (2020) analysed the social and economic impacts of proposed changes in the road network around Dunedin Hospital. The analysis measured the impact of a change in the features of roads on the composition of business activities in a suburb. The study investigated likely changes in the location of households based on the new composition of businesses across the region. The analysis discusses that improved street access leads to relocation of various businesses and economic gains from agglomeration benefits. The additional benefits go to households that enjoy using the services provided by the activities that have emerged, but this comes at a cost to other businesses and households.

2.4.4 Weighted benefits within a cost–benefit analysis

Section 2.3.5.2 gives a description of equity weights as a method of quantifying equity. The process that defines weights in a CBA is based solely on the amount of money individuals are willing to pay (from their private income) to achieve certain outputs (impacts).

To use distributive weightings as a form of mitigation, it is necessary to acknowledge that people with higher incomes can pay more for their desired initiatives, which may lead to constantly lower benefits for the low-income group. To address this, Anciaes and Jones (2020) suggest that equity should be assessed using ‘equity values’ or by weighting impacts relative to income.[38] They also suggest that weights could be applied to analyses based on need or vulnerability, to explicitly promote the welfare of some groups.

The basis for the weighting recommended in the UK’s Green Book (HM Treasury, 2020) is the principle of diminishing marginal utility of income, which states the value of an additional dollar of income is higher for a low-income recipient and lower for a high-income recipient. Using equivalisation techniques, the Green Book applies a scaling factor to household income to adjust for composition (factors such as age, income and size) to standardise the welfare impact.

To derive the distributional weight, the Green Book divides the median equivalised income of average taxpayers (proxied by median of all households) by the median equivalised income of programme participants (proxied by the quintile that matches the target for distributive effects) and raises it by the power of 1.3, which is the elasticity of marginal utility of income. In the UK, this gives a multiplier of 2.4 (using 2015 data) (Fujiwara, 2010). To calculate the weighted redistribution impact on the society, the Green Book’s method is to multiply the change in income of participants by the estimated weight (2.4) and add that to the change in income of non-participants.[39] The Green Book notes the uncertainty in both weighting and equivalisation methods and suggests accounting for this by using sensitivity analysis (HM Treasury, 2020).

Boardman (2018) provides further technical details about using weights in CBA. Accordingly, the only CBA guideline that recommends using weights is the UK’s Green Book. Boardman suggests the lack of consensus for using distributional weights is because it is difficult to reach a set of weights that are widely accepted (except for global-wide studies of climate change). He suggests the use of distributional weights should be limited to the policies for which they are of central concern. This includes policies aimed at disadvantaged groups or improvised areas or that explicitly treat socioeconomic groups differently.[40]

The Australian Transport Assessment and Planning Guidelines (Transport and Infrastructure Council, 2016, p. 16) explicitly rule out the use of distributional weights for transport appraisals in Australia. This is because the Transport and Infrastructure Council recommends distributional judgements be made at the political level, which is in contrast with the use of equity weights in CBA.

2.4.5 Complementary use of cost–benefit and multi-criteria analyses

Multi-criteria analysis, sometimes referred to as multi-criteria decision-making analysis, is another option-ranking process used as both an alternative and complement to CBA. The two main stages of MCA are to:

- Identify criteria against which to test the options.
- Weight (or score) the criteria to arrive at a ranking of options.

The Waka Kotahi manual for MCA suggests the project team should choose the criteria to be considered from a list they have provided (Waka Kotahi, 2020, pp. 7–8). The manual then suggests a sensitivity analysis for the evaluation of the impacts of each criteria (and their weight) on the overall assessment.

---

[38] Anciaes and Jones (2020) investigated the available solution for incorporating social equity in transport appraisals and report that equity is usually assessed by disaggregating impacts by social group.

[39] Impact on society = change in income of the participant group * welfare weight + change in income of the taxpayer group.

[40] Boardman (2018) suggests a policy and/or programme needs to use distributional weights when it meets both of the following conditions:

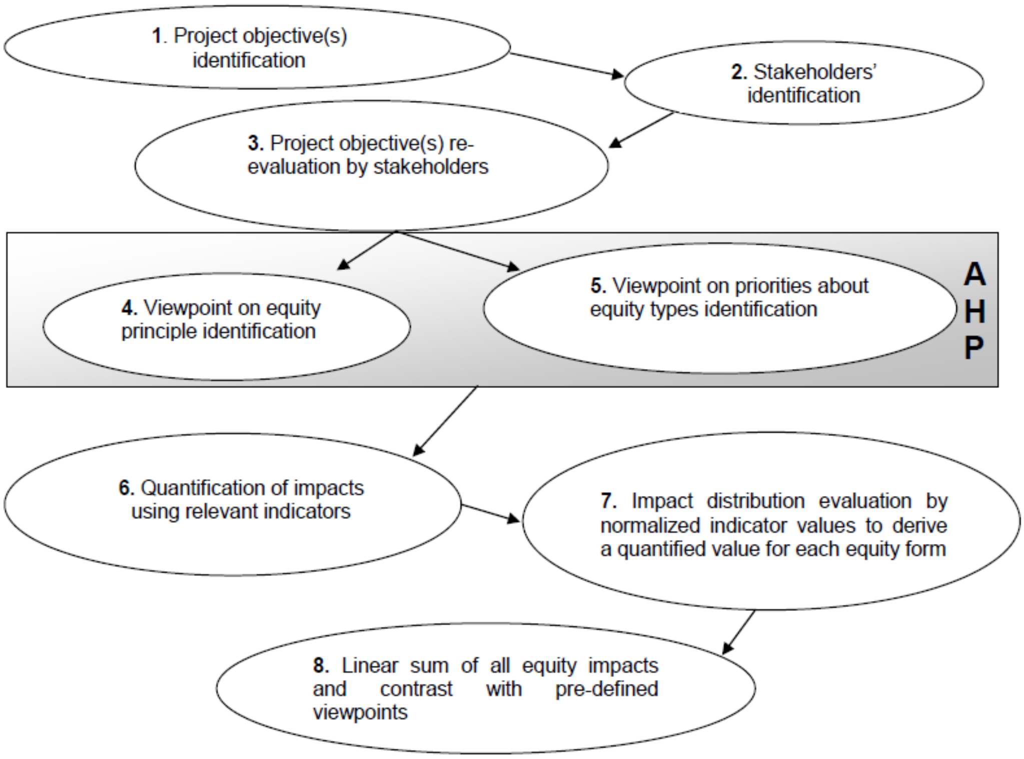
a) Targeting the disadvantaged or having different implications for advantaged and disadvantaged groups
b) Leading to a reduction (an increase) in overall societal efficiency but having a positive (negative) impact on the low-income group.

Various studies in the literature discuss the importance of weighting and the methods for estimating the weights. An example of an MCA with relevance to equity is Thomopoulos et al. (2013, p. 7), who note that:

> *There are also criticisms of MCA – weights must be attributed to each criterion, bringing subjectivity and it is potentially time consuming and complex. Nevertheless it adds transparency to the appraisal as decision makers are required to consider and express their preferences based on the overall project or policy objectives.*

The authors investigated a solution for equity considerations in the appraisal of transport projects and suggest that MCAs offer a flexible approach for combining the competing technical, environmental, socioeconomic and political interests in transport decision making. The approach of Thomopoulos et al. is based on the analytical hierarchy process, which estimates the contribution of each criterion (within an MCA) towards the overall goal.[41] Figure 2.10 shows the eight stages of MCA as suggested by Thompoulos et al.

Figure 2.10 Eight stages of considering equity impacts in multi-criteria analysis



Source: Reprinted from Thomopoulos et al. (2013, p. 10)
Note: AHP = analytical hierarchy process.

[41] The 'AHP [analytical hierarchy process] begins by arranging the elements of the analysis in three main hierarchical levels. The overall goal of the decision-making problem at the top (e.g., satisfaction with a transport policy option); a set of decision criteria in the middle layers (e.g., factors that influence the satisfaction of transport policy options); and a group of competing options at the bottom (e.g., transport policy options). Next, the relative importance of each criterion with respect to the goal of the analysis is determined through a series of pairwise comparisons of criteria. The subjective judgments of experts or policy makers regarding the relevance of the different criteria are translated into a quantitative score and subsequently the most desirable option can be determined' (Mouter, 2021, p. 232). The analytical hierarchy process is one of many sophisticated methods available for multi-criteria analysis (MCA).

Like CBA, MCA has a history in social choice theories (Tsoukiàs, 2008) but the two diverge when it comes to the weighting of criteria and the measurement of effects. Both condense a lot of information into a single summary measure of preferences. Unlike CBA, many variations of MCA exist (Shortall & Mouter, 2021).

The CBA weighting process is implicitly determined by the preferences of the individuals affected by the policy change or investment; the individuals are weighting various criteria, including social and environmental effects, in their monetary compensation assessment. This weighting of criteria is done more transparently in an MCA, although more subjectively.

The measurement of effect in a CBA is given by the monetary compensation equivalent to the proposed change attributed to the individuals affected by the policy. Measurement of effect in the MCA is done more explicitly, sometimes by subject-matter experts and sometimes by representative stakeholders, but in both cases as judgements on behalf of the individuals affected.

A survey of 21 Dutch transport politicians by Annema et al. (2015) found that no one tool was any better at providing transparency, process and the presentation of trade-offs. Elsewhere, CBA has been described as more rigorous, transparent and formal, while MCA is better at enlarging 'democracy' in terms of public debate and useful for settling possible arguments and revealing preferences and priorities (Beria et al., 2012). Likewise, MCA is seen as methodologically suitable for dealing with multiple viewpoints and value dimensions (Shortall & Mouter, 2021).

An often-reported conclusion is that CBA and MCA should be used together (Annema et al., 2015; Beria et al., 2012; Shortall & Mouter, 2021).[42] However, just how that should occur appears unresolved and the risks of dual appraisals include double-counting and ambiguity.

Three ways that CBA and MCA are combined are as follows:

- The CBA is used to show the option passes of a benefit–cost ratio threshold and then the MCA establishes priority (which is like use of the CBA within the Waka Kotahi priority tool[43]).
- The CBA provides the measurement for a value-for-money criteria within an MCA (like the practice in the Waka Kotahi guide).
- Results of CBA and MCA are compared to find a recommended solution (again, a variation of the Waka Kotahi priority tool). Barfod and Leleur (2014) provide a formal method to combine the two techniques, which involves weighting two values, one derived from CBA and the other from MCA.
- In using the CBA and MCA, researchers need to be wary of double counting either benefits or costs.

2.4.6 Equity mitigation strategies

Along with the transport mitigation methods, which highlight the importance of equity in the cost-effectiveness analysis, equity mitigation strategies could be used for addressing unintended distributional impacts.

Litman (2022, pp. 21–22) discusses mitigation policies and notes that 'mitigation strategies should reflect community needs and values, so affected stakeholders, particularly disadvantaged communities, should be involved in planning'. Litman classifies the mitigation strategies as categorical and structural solutions, defined as follows:

---

[42] Beyazit (2011) proposed a dual CBA–capabilities approach where the capabilities assessment is like an MCA undertaken by the affected transport users.

[43] See https://www.nzta.govt.nz/planning-and-investment/planning/investment-decision-making-framework-review/investment-prioritisation-method/, for more information.

- Categorical solutions include the policies or programmes that target specific disadvantaged groups. These include programmes targeting people with disabilities, fare discounts for seniors and students, and special commuter bus services in high poverty areas. These solutions are usually more cost-effective because they target a limited (usually small) group of people.
- Structural solutions include the planning practices targeting a more diverse, affordable and efficient transport system. Examples include multimodal planning, efficient pricing reforms and the development of policies that create more affordable housing options in walkable neighbourhoods. Compared with the categorical solutions, structural solutions are usually associated with a wider range of outcomes and a more radical change in the transport system.

3 Measurement and mitigation

This chapter uses a hypothetical example to look at the practical implications of using alternative distributional weights within a CBA. We develop a set of weighting options likely to be viable and criteria against which to judge each method. We discuss the pros and cons and recommend a way forward.

The chapter focuses on the measurement of benefits to be included in a CBA. It is noted and assumed the CBA fits within a decision-making framework that, where appropriate, includes community engagement, social impact appraisal, optioneering, multicriteria analysis and, ultimately, option prioritisation and a decision.

3.1 Step-by-step distributional weighting

Chapter 2 provides a range of literature relevant to distributional weighting within a CBA. This section outlines the main steps required to be taken when applying distributional weights, using a hypothetical example and earlier research to draw out important issues and consequences.

1. Step one is to note that the inclusion – or not – of distributional weights within a CBA of a public policy intervention is contentious (Boardman et al., 2020; Brent, 2006; Dobes et al., 2016).
2. Many authors have noted that any CBA, including the status quo methods applied in transport, already has a weighting method applied, but some researchers have argued the weighting method can be made more explicit and other methods should also be considered (Adler, 2019; Brent, 2006).
3. Most (if not all) researchers agree that an economist's role when estimating a CBA is not to make value judgements but to explain the implications of them (which are invariably required to be made in public policy and investment decisions), so, even if other weights are used, the recommendation is to report each benefit measure (Adler, 2019; Boardman et al., 2020; Creedy, 2006). This is also recommended practice in the UK (Green Book, HM Treasury, 2020) and Australia (Australian Government, 2020).
4. The choice of weighting method is typically presented as being determined by whether the CBA's focus is on efficiency or equity (Boardman et al., 2020; Brent, 2006). Both concepts can, however, have multiple meanings. In practice, as shown below, the CBAs currently applied by Waka Kotahi and major transport authorities worldwide already combine these concepts and do not provide an unadjusted measure of monetised efficiency, nor of equity.
5. The efficiency argument is that the CBA measures the willingness of individuals to pay for some benefit and the willingness of others to accept an accompanying cost. If the sum of these amounts (positive for benefits, negative for costs) is a positive number and if these people were to make these payments, as if goods or services were being traded in a private market, then a Pareto improvement would have occurred; that is, some people will have been made better off without anyone being made worse off. This is considered a more efficient allocation of resources.
6. An important assumption is that markets are perfectly competitive and the economy is operating at full capacity. Waka Kotahi has already considered ways in which these assumptions may break down (Kernohan & Rognlien, 2011) and now includes wider economic benefit factors in a CBA. Another research strand looks at the possibility that capacity could be expanded further by taking a capabilities approach (Beyazit, 2011). This issue is discussed in section 3.3.4.
7. A further issue with a social CBA is it requires the willingness to pay and accept money to embrace various social, economic and environmental effects. This presents a large measurement challenge. The typical approach is to rely on averages derived from various evidence bases and apply the above logic to people as a large group. Disaggregating groups further to consider distributional effects creates an even larger measurement challenge (Boardman et al., 2020).

8. More fundamentally, sometimes the abstraction will simply not be appropriate, either because the transfers do not happen and so a Pareto improvement does not eventuate, or because willingness to pay and/or accept are not known (to the individuals and/or analysts making the estimation), or because some people are simply not willing to accept the cost. These three issues are discussed next.
9. An exchange of payments rarely occurs. Instead, analysts and decision-makers fall back on the Kaldor–Hicks principle and assume such an exchange is at least possible. Some have argued that the benefits and costs will even out, to an extent, over many projects (Boardman et al., 2020) and it is the role of taxation and wider public policy to address inequities (Boardman et al., 2020). However, times may occur when the public prefers in-kind transfer (for example, road taxes being applied to create bus infrastructure for deprived areas) for one or both of the following reasons. First, the transfer of resources could be administratively cheaper than going through an income transfer system (Gramlich, 1994). Second, those richer individuals providing funds may prefer to direct the transfer to explicit consumption items (in this case, transport, but in other cases it may be food or schooling or health) (Brent, 2006). This raises two questions:

    a. Will a transport intervention achieve a desired redistribution more efficiently than a wider public policy response?

    b. Do the wider public, particularly any richer people providing public funding,[44] prefer in-kind transfers via the transport system?

    These matters <u>could</u> (potentially) both be monetised and included in a social CBA, but is unclear whether agreement has been reached on whether they <u>should</u> be included. As noted, a consensus is likely that these matters are difficult to measure and, if they are included, the results should clearly show the calculations and state the assumptions.
10. The second area listed above, where the abstraction breaks down, is when the willingness to pay–accept is uncertain. This interacts with the distributional effects of a transport project in two major ways. The first is when it is unclear how future generations, or even the current generation in future years, will be willing to pay–accept and/or as to how this future payment would be valued today (that is, what discount rate to use). The second is when the effect on an individual or group is uncertain, which can apply now and/or in the future. An example of a current uncertainty is the question of who benefits from a lower trucking cost (due to, say, faster travel times): the trucking company, local residents or the consumers of trucked goods in distant regions?[45] An example of a future uncertainty is how much will a current transport intervention reduce future carbon emissions and what will future generations be willing to pay for carbon emission reductions today (we may not currently know the quantum and the price)? As above, these matters are relevant to a social CBA but are hard to measure, and the consensus appears to be that, if included, <u>measurement uncertainties should be clearly identified</u>.
11. The third problem listed above relates to intangible values. If a benefit or cost cannot be quantified, then it cannot be within a CBA. This is a truism. The matter of contention is whether something is truly intangible. Rather than enter into that debate, two common practices can address this issue, should it arise:

[44] An even wider viewpoint is it is the political system that 'allows' some individuals to be wealthier, and so it is not necessarily the preferences of the rich that determine the appropriate means of resource transfer.

[45] A general equilibrium approach could explain the wider benefits from the lower trucking cost and provide further information on the incidence of benefits.

   a. The CBA can at least be used to calculate the pivotal monetary threshold that would affect a choice between options (for example, it would cost $X more if a new highway is not routed through a cemetery).

   b. The CBA is rarely used as a decision rule but rather sits within a wider decision-making framework (Boardman et al., 2020). This suggests the more practical question is: what can be done within a CBA that cost-effectively complements the wider decision-making framework?

12. The last three points follow from the idea offered above that the social CBA compares monetised benefits and costs. This does not need to be the case; it is merely a convenient representation of the wider issue of improving the collective wellbeing (that is, the social welfare) of a group of people. The monetisation process allows recourse to the Pareto principle but is constrained by the current allocation of resources. It is well known (Martens, 2006) richer people will be able to pay more, but it is widely believed that the incremental benefit to a rich individual – in a wellbeing or utility sense – does not need to be any greater than that received by a less-wealthy individual with a lower willingness to pay. In other words, the marginal utility to income generally declines. So, while a monetised CBA may indicate that a policy change can create an increase in collective wellbeing, this may not be the optimal reallocation of resources in terms of collective wellbeing.

    It is likely a more efficient allocation of current resources, in terms of collective wellbeing, would be a reallocation to the less wealthy, particularly to those most deprived, but this goes beyond Pareto optimality. This is not a contentious statement but, again, the challenges are:

    a. Can this wellbeing change be measured?

    b. How will this affect dynamic efficiency; that is, how does the current allocation of resources affect the future growth of resources?

    The issue of measurement has been widely discussed. The issue of dynamic efficiency, which is part of the uncertainty of future effects discussed previously, is seldom mentioned in the literature relating to distributional weighting within a CBA. These are again reasons to understand how a CBA weights and reports the benefits and costs of individuals, or groups of people, but not necessarily reasons for a CBA to ignore difficult-to-measure distributional effects.

13. The most <u>common broader social welfare approach is to estimate and apply the marginal utility of income</u>, effectively giving more weight to the monetary benefit to low-income earners and less weight to higher-income earners (Adler, 2019; Brent, 2006). Issues with this approach, such as individual utility from goods and services changing over time, will be put aside in favour of considering how this approach can be applied.

14. Adjusting for the marginal utility of income has been operationalised in the UK (Green Book, HM Treasury, 2020), with the weight to apply for a group being the ratio of the median national annual income to the group median income raised to the power of 1.3. For example, if the group median income is $25,000 per year and the median national is $50,000 per year, then the group's monetary benefit (or cost) will be multiplied by $2^{1.3}$ and, conversely, another group with a median income of $100,000 per year would have their benefits (or costs) multiplied by $0.5^{1.3}$. Variations of this are different measures of 'income', such as after-tax income or after-tax and after-housing costs income (Department for Business, Energy & Industrial Strategy, 2018).

15. This weighting system is consistent with the method of calculating the widely used Gini coefficient but requires an assumption about the welfare function (Brent, 2006). This is an assumption by the analyst, however, and amounts to value judgements unless clearly communicated as alternative measures (Brent, 2006).

16. One argument is that at least the widespread use of the Gini coefficient justifies this approach. It can also be said, however, that the current CBA method is widely used. Neither is a strong argument in each other's favour (Brent, 2006).
17. Brent (2006) also showed the welfare weighting method, as described above, can be reduced to a measure of the average effects and the effect due to inequality. This is discussed in the next section.
18. Rather than explore other welfare function assumptions that could be made, we look instead at practical issues with estimating and combining the distributional effects within a CBA, but note that:
    a. Distributional weights within a CBA have, to date, largely related to income (and not to other factors that may create disadvantage).
    b. No empirical or theoretical reason exists to determine the 'best' weighting method (including the implicit weighting widely used within currently applied social CBAs).
19. The first step in determining a distributional effect is to measure benefits and costs by groups. This is recommended when equity issues are expected to be important (for example, in the UK and Australia). Dobes et al. (2016) refer to a generic tableau format that can be used to show gross and then net effects. The UK Green Book provides a guide as to which groups to disaggregate from the rest, as well as the weighting by income method above (HM Treasury, 2020).
20. Consider a hypothetical transport project. Say a road blockage is forcing traffic to be diverted through two suburbs, a rich and a poor suburb (with median household incomes taken to be the New Zealand fifth and first quintiles, respectively, as at 2019/20). For some reason, a rule requires the diversion to be concentrated in one suburb and decision-makers propose it should be through the rich suburb only. Under the proposal, there will be travel benefits to the local road users in the poor suburb and travel disbenefits in the rich suburb. For this exercise, these benefits and disbenefits are considered to be of the same physical magnitude in each suburb (but not necessarily of the same 'value'). Assume the rule change will not lead to other cost changes so the distributional analysis only concerns the benefits. So far, we have mentioned (briefly) four weighting methods: the unadjusted CBA, the CBA as typically applied in transport studies, a welfare-weighted CBA using income ratios and a CBA that shows the threshold.
    a. The status quo CBA would neither support or oppose the change because the benefit in the poor suburb is offset by the disbenefit in the rich suburb, because an average WTP has been imposed for all travel of the same purpose and mode as an institutional rule (that is, a value judgement).
    b. The unadjusted CBA that better represented the rich and poor, respectively (a square-root relationship between WTP and income has been assumed here; Waters, 1994), would show people in the rich suburb could each pay $17 or more to reverse the rule proposal.[46] This policy reversal would be sure to create a Pareto improvement (assuming certainty about numbers) if the poor suburb were to be compensated for taking on the extra travel cost and those in the rich suburb would

[46] The $17 is calculated using the square-root formula and based on the figures provided in Table 3.1. The square-root formula is as follows:

$$WTP_i = \sqrt{\frac{income_i}{income_{average}}} \times WTP_{average}$$

Accordingly, WTP of the lower income group is calculated as follows:

$$WTP_{poor} = \sqrt{\frac{19549}{41472}} \times 25$$

not incur any extra travel costs. This, however, ignores the issue that such compensation rarely occurs.

c. The welfare-adjusted CBA would show the initial proposal was consistent with evidence elsewhere that the welfare gain to the poor suburb would more than offset the welfare loss to the rich suburb, given their higher welfare gain per dollar. It would not indicate how this might affect the future growth rate of either suburb, nor of the wider region.

d. The fourth approach starts from the alternative option. If traffic were diverted to the rich suburb, the monetary equivalent of the welfare loss to these people would be $17 (that is, the opposite of the $17 gain in Table 3.1) and the monetary equivalent to the welfare gain in the poor suburb would be $54, effectively a transfer from the rich to the poor. If general taxation (or similar) were instead used to redistribute $17 to the poor, and we assume a 50 percent transaction cost and that the rich pay all the tax costs, then the cost to the rich would be 1.5 times $17; that is, $26. This tax cost is less than the $54 cost in the transport project, so does not offer any support to the case that redistribution via this transport project would be more efficient than via general tax and income policies. However, if the transport cost to the rich suburb were, say, $20, then it could be inferred using this weighting method that the transport project offered a more efficient method to redistribute income. Unfortunately, this example does not suggest which option is preferable because it, like (b), ignores the transaction costs that would be required to compensate the poor under the proposed option.

Table 3.1 Weighted benefits per person-hour using a benefit-only example*

Disaggregation	Income	Benefit	a) Equally weighted AVERAGE WTP (status quo)	b) Equally weighted INDIVIDUAL WTP	c) Weighted CBA (as per UK Green Book[†])
Benefit$_{rich}$	$81,054	–$35	–$25	–$35	–$17
Benefit$_{poor}$	$19,549	$17	$25	$17	$54
Total benefit			$0	–$18	$37

Source: Principal Economics

* At an average income of $41,472 and average WTP=$25.

[†] HM Treasury, 2020.

Note: CBA = cost–benefit analysis; WTP = willingness to pay.

21. This example has already shown the difficulties in all four CBA approaches. The status quo does not recognise a welfare improvement is possible if monetary compensation occurs. The unadjusted CBA recognises one form of efficiency gain is possible, but history shows that compensation rarely occurs. The welfare-weighted CBA recognises that welfare gains disproportionate to incomes are possible, even probable, given these numbers, but offers little confidence the estimated gains are correct and, importantly, provides dollar amounts that are not immediately recognisable by decision-makers (the poor suburb does not receive $54 more; it receives $17 more, which translates into the welfare that the average person could buy with $54). Last, the fourth approach can show, if redistribution was an objective, the occasions when a transport policy can provide an efficient means of redistribution but likely only for a subset of projects and creating different inequities in the process. For example, people in the rich suburb in this example would be paying disproportionately more than the general rich, tax-paying population of New Zealand.

22. Again, hypothetically, it is possible, were the transfer to occur, the rich suburb residents would prefer it to happen through the transport system. The underlying inference of many accessibility studies is either (a)

people have a right to some (undefined) minimum level of accessibility and/or (b) a person's disadvantage can be significantly improved or overcome through better accessibility. These two potential effects could be why people in general favour in-kind transfers of transport resources to disadvantaged people. Potentially, this WTP could be incorporated into any of methods (a) to (c) above. However, any potential rights, effects and public preferences are still the subject of research.

23. The above example could also be extended to a third suburb with average incomes and the same physical effects as the other two suburbs. The benefit to this suburb would be $25 whether measured by the current, unadjusted or welfare-weighted CBA, reinforcing the point that adjustments in these methods are relative to the 'average' (sometime median).

24. Consider the cost side of the equation, because a full distributional social CBA would show the benefits and costs for each group. This introduces the issue of how funding for schemes would be raised. The three most common funding sources in New Zealand are pools of local government rates, central government taxation or hypothecated transport charges. All three lead to higher income households generally paying disproportionately more. If we assume roughly that the top quintile of households contributes around 35 percent of transport funding, the bottom quintile 10 percent and middle quintile 55 percent, and the above example came with a $10 cost for each option, then the distributional CBA implications of weighting methods (a) to (c) above can be shown below. In each case, funding has come from a general pool rather than specifically funded by project, as is the general situation in New Zealand.

    a. The status quo ignores any distribution of costs.

    b. The unadjusted CBA would recognise $3.5 funded from the rich suburb, $1.0 from the poor suburb and $5.5 from the rest under all project options (see Table 3.2). So if the diversion project were chosen to favour benefits for the poor suburb (that is, diverting through-traffic to the rich suburb), an implicit redistribution of resources to the poor suburb does occur due to the institutional funding arrangements not currently recognised in a status quo CBA. This would be recognised in an unadjusted CBA and so would interact with the redistribution effect due to benefit differences.

    c. Applying welfare weight would again show the welfare burden of the (relatively small) funding cost to the poor suburb is greater than the financial burden, and could possibly be greater than that of the rich suburb <u>if</u> these welfare weights reflect the actual situation.

Table 3.2 Costs per group for a project (in any location) that costs $10 (approximate only)

Disaggregation	Income	Cost	a) Equally weighted AVERAGE COST (status quo)	b) Equally weighted INDIVIDUAL COST*	c) Weighted COST (using UK Green Book benefit weighting method†)
$Cost_{rich}$	$81,054		Not applicable	$3.5	$1.5
$Cost_{poor}$	$41,472		Not applicable	$5.5	$5.5
$Cost_{poor}$	$19,549		Not applicable	$1.0	$2.7
Total cost		$10.0	$10.0	$10.0	9.6

Source: Principal Economics

* The cost is not a willingness to accept amount but an imposed resource cost.

† HM Treasury, 2020.

Note: CBA = cost–benefit analysis; WTP = willingness to pay.

25. The <u>UK's DfT approach is to not welfare-weight funding costs</u>. This is recommended here. Again, measurement issues exist and wider institutional arrangements are in place but, importantly, any adjustment to the pooled cost does not change the relative NPV of projects. The institutional

arrangements are worth further discussion. Waka Kotahi does consider imbalances in allocation of funding to regions in its decision-making process, and partly corrects for potential redistribution of funds, although this balancing is imperfect and no formal consideration occurs of projects within a region (although political pressure provides a counter to any imbalances).

26. The above example is framed so it fits with private vehicle usage. In this situation, the WTP of richer people has been widely reported, although the wealth or income comparator of relevance can vary household income in some cases and personal income in others (Arup, 2015). An alternative framing of relevance relates to public transport projects. These differ in important aspects: public transport WTP has been found to have much lower elasticity to income (Arup, 2015), and transport modellers typically employ a model of aggregate behaviours that is not easily transformed to measures of individuals. To illustrate the different weighting methods applied to a public transport project, the value of travel time saving elasticity to income for a bus project has been set at zero in the following example.

27. Reconstructing the earlier example for a public transport situation and using the same quantum of benefits but with benefits now only delivered to public transport users (that is, no travel time savings for other road users), the three methods would show:

    a. the same benefit outcome as previously under the status quo CBA

    b. the unadjusted CBA would also show an NPV of zero (so other factors would influence the decision, including possibly equity considerations)

    c. the welfare-weighted CBA would again estimate higher (welfare) benefits to the poor suburb (Table 3.3).

Table 3.3 Weighted benefits per person-hour using a benefit-only public transport example*

Disaggregation	Income	Benefit	a) Equally weighted AVERAGE WTP (status quo)	b) Equally weighted INDIVIDUAL WTP	c) Weighted CBA (as per UK Green Book†)
Benefit$_{rich}$	$81,054	–$25	–$25	–$25	–$10
Benefit$_{poor}$	$19,549	$25	$25	$25	$66
Total benefit			$0	$0	$56

Source: Principal Economics

* At an average income of $41,472 and average WTP=$25.

† HM Treasury, 2020.

Note: CBA = cost–benefit analysis; WTP = willingness to pay.

28. The example further shows the measurement challenges: how much confidence can be put in the welfare measurement? Can we reasonably attribute and measure benefits to different user groups? These measurement challenges are compounded by adding in a combination of public transport and other road user benefits, as is more likely the case in reality.

29. Another difference can be seen between a public and non-public transport project of relevance to equity. Martens and Di Ciommo (2017) discuss five ways where the use of travel time savings interacts with equity issues. In combining these five issues, a standard CBA today will recognise the expectation of travel time savings for transport projects, but these savings are often not sustained over time (or as modelled). This shows the uncertainty of transport modelling (and any modelling of future effects) but also implies a persistent bias in appraisal. This bias is tolerated possibly because, even if the travel time savings are eroded over time (that is, they occur initially but are eventually eroded by induced traffic), a

benefit is still gained in the form of higher GDP, including higher agglomeration effects,[47] resulting from the above-expected activity levels. So, while the projected travel time savings benefits do not eventuate, the actual benefit received may be of a similar size or possibly higher. In a sense, the industry is applying a 'put option' approach: invest in roading expected to deliver more activity and if higher activity does not occur then the investment falls back to the travel time savings. Either way, the investment is of value. However, what if the same expanded activity scenario is possible under a public transport-led approach, which is quite likely. If so, the added advantage is of providing a more equitable network. A public transport appraisal, however, typically does not have the initial scale of patronage to provide the 'put' value; that is, if the higher level of activity does not emerge then the fall-back situation of current (and forecast) public transport users enjoying benefits does not typically add up to much. From this perspective, a major difference between public and non-public transport appraisals revolves around the forecasting and certainty of induced demand. This is possibly an area where equity issues may be more directly addressed within the current CBA and transport modelling approach. This is discussed further below.

3.2 Criteria

Before outlining alternative methods to account for equity within a Waka Kotahi CBA, it is useful to specify criteria for assessing the suitability of each approach. The following criteria were used to inform the recommendation of methods and measures. They are similar to those set out by Beyazit (2011), Shiftan et al. (2021) and van Wee and Geurs (2011):

- Fit of the method with the joint GPS, transport outcomes, investment decision-making, MBCM process
- Use of the method elsewhere in the world (enables pros and cons to be assessed more fully)
- Materiality of equity effect expected
- Ability of the method to measure effects for target groups of interest in New Zealand
- Cost of analysis (some methods may be suitable for large projects but too costly for smaller ones). Note that cost is also used as a proxy for 'ease of analysis'
- Whether measurement occurs in the primary (transport) or secondary market; the former more readily fitting with CBA at present
- Data and/or model availability to New Zealand business case analysts
- Ease of communication.

3.3 Possible approaches

Based on our literature review, the following methods for including consideration of equity within a CBA are judged most suited at present to Waka Kotahi, including the status quo for comparison:

A. The status quo.

B. Status quo with more sensitivity analysis. Undertake more analysis, where required, using status quo methods such as sensitivity and scenario analysis. In particular, further analysis could be undertaken around induced demand assumptions, especially public transport demand, where the population affected by the project is heterogeneous and the evaluation period and discount rate are worthy assumptions to reconsider when intergenerational distribution issues are likely to be significant.

C. Welfare-weighted, apply the Green Book income-adjusted weights (HM Treasury, 2020).

[47] For further discussion, see section 2.3.4.

D. Build a bottom-up CBA based on accessibility and possibly capability building (de Jong et al., 2005; Nahmias-Biran & Shiftan, 2016; Shiftan et al., 2021).

3.3.1 Method A: Status quo including reporting distributional benefits

The status quo already includes provision for reporting distributional benefits, without weighting:

> *While an analysis of the distribution of benefits and costs among different groups of people is not required for economic efficiency analysis, evaluations of an activity should report the distribution of benefits and costs, particularly where they relate to the needs of transport disadvantaged populations. This reporting forms a part of the funding allocation process. When it is required, distributional effects should be reported separately from, but alongside, the CBA results.* (NZ Transport Agency, 2020, p. 16)

Suitable disaggregation is likely to be as shown in Table 3.4, and as recommended in the UK (and previously discussed in section 2.2.7.2). Other lists are provided, as reported in section 2.2.5.

Table 3.4 Scope of socio-demographic analysis for distributional impacts as defined by the Department for Transport

Social group	User benefits	Noise	Air quality	Accidents	Security	Severance	Accessibility	Affordability
Income distribution	✓	✓	✓					✓
Children: aged under 16 years		✓	✓	✓	✓	✓	✓	
Young adults: aged 16 to 24 years				✓			✓	
Older people: aged 70-plus years				✓	✓	✓	✓	
Population with a disability					✓		✓	
Population of black minority ethnic origin					✓	✓	✓	
Households without access to a car						✓	✓	
Households with dependant children							✓	

Source: Adapted from DfT (2020a, p. 6)

It is unknown to what extent the current measurement methods listed in the MBCM are being applied fully. A suggested workflow is provided below.

Step 1. Assess to what extent people in the project area differ from the national average. This can then be used to identify situations where inequities related to the transport project may occur (step 2). It is expected this step will follow directly from an earlier social impact assessment (NZ Transport Agency, 2016), which has likely led to (costly) refinements of project options. The aim is to ensure all corresponding social benefits are measured within the CBA, if material.

Step 2. Use the above difference-from-average summary to pinpoint significant social disadvantages that transport projects have historically either worsened or reduced. Table 3.4 provides an initial checklist. A more extensive checklist showing links to sections of the MBCM and Waka Kotahi non-monetised benefit and cost manual is provided in Appendix E.

Step 3. Calculate and report the distribution of benefits by national income quintiles (as per the DfT). This disaggregation can be later used within an MCA and also feeds into scenario 3 under method B.

3.3.2 Method B: Status quo with more sensitivity analysis

Method B is presented as a separate option, partly to emphasise the role that sensitivity analysis could play and because it provides an enhancement that does not rely on the measurements required in method D, as discussed below.

The previous chapters discuss ways in which people may be disadvantaged by transportation, and/or how disadvantages that they otherwise experienced could be mitigated by transport policies and investments. One way in which the current CBA approach can be enhanced, to capture distributional benefits, is to identify transport situations where these risks and opportunities exist and then target sensitivity and scenario analysis to ensure the full potential for benefits is being measured.

The scenarios envisaged could entail changing inputs such as: a key benefit parameter, the extent of induced demand, the duration of benefit effects, the discount rate. This approach does not explicitly identify the distributional benefit but rather ensures wider consideration is given in areas where equity effects are likely to matter. The literature review chapters identify that such areas include:

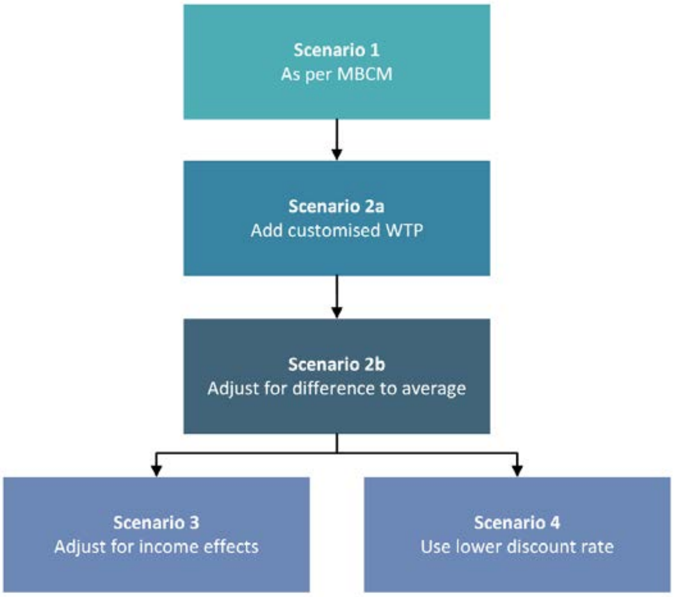
- study areas that span heterogeneous populations
- bus projects and, to a lesser extent, rail
- projects with climate change effects (mitigation and adaptation).

It is recommended measurements for five scenarios[48] are made and reported where large distributional effects are anticipated. The scenarios aim to progressively address specific uncertainties around current MBCM measurements: the manual does not specify measurements for all benefits; the measurements typically apply to the average person whereas the target population may differ; the measurements are based on average WTP when (income-adjusted) marginal utility may also be of interest; and situations occur where the use of a standard discount rate is not ideal. Not all CBAs need all scenarios but communication advantages are gained in applying a standard hierarchy and labelling.

We provide further details on different scenarios below, as show in Figure 3.1.

[48] This initial recommendation for five benefit measurements is subsequently reduced to four (by collapsing scenario 2a and scenario 2b).

Figure 3.1 Building up standard scenarios to examine uncertainties



Source: Principal Economics
Note: MBCM = Waka Kotahi monetised benefits and costs manual; WTP = willingness to pay.

Scenario 1. This is the status quo method above. Note the parameter values within the benefit calculations are for the average person, applied in different transport situations. The MBCM measurements are generally expected to capture the major benefits although times will occur when distributional and/or uncertainty effects may materially cast doubt on the completeness of scenario 1.

Scenario 2a. This intends to add, where material, measurements of benefits and disbenefits not included in scenario 1. The advantage of separating the two totals is that scenario 1 provides a more certain and consistent benefit measure while scenario 2 is expected to provide a fuller, but probably less accurate, estimate of total benefits. It is likely measurements here will be drawn from such sources as the Waka Kotahi non-monetised benefit and cost manual and CBAx and, in time, be incorporated in the MBCM as confidence in the benefit measure increases (and no doubt other unmeasured benefits will also come to the fore).[49]

Scenario 2b. This intends to take scenario 2a (or scenario 1, if no extra measures are undertaken) and show adjustments of WTP to account for any difference in the composition of the target population from the national population (from which the average WTP was derived). For example, a higher WTP is likely for safety and security features in a project area where the proportion of children is higher than nationally. Note this is not an effect due to income but reflects preferences of the average person.

Scenario 3. This takes scenario 2b and adjusts for the decreasing marginal utility from income, effectively providing a standardised and simplified version of method C. It uses the distribution of benefits from step 3 in method A (which is also scenario 1) to estimate the monetary benefit that would exist if all people received the same average income. This scenario fundamentally differs from scenarios 1, 2 and 4 because it does not necessary imply a situation where compensation ensures a Pareto optimum could be achieved. It does, though, provide a transparent and consistent method to consider wellbeing, although uncertainty exists about the accurateness of the results. The measurement method will be relatively more favourable to

[49] A recent example of a measure suited to scenario 2 is the addition of extra social inclusion benefits for new trips generated from those zones in Sydney estimated to be at ‘moderate’ or ‘most’ risk of mobility-related social exclusion (Stanley et al., 2021).

transport options that improve situations for lower-income people. It is expected use of scenario 3 will build awareness, research and confidence in the use of welfare weights, and so is envisaged as a learning opportunity as well as a source of information for current investment decisions.

Our suggested welfare weight calculation is to first estimate WTP for income group and then apply Green Book (HM Treasury, 2020) welfare weights (where 'average' below is the national average):

Estimate WTP for income group i as $WTP_i = WTP_{average} * SQRT(income_i)/SQRT(income_{average})$ (Equation 3.1)

Estimate weighted WTP for income group i as $wgtWTP_i = WTP_i * (income_{average}/income_i)^{1.3}$ (Equation 3.2)

Scenario 4. This also takes scenario 2b and applies a lower discount rate. Research suggests a lower discount rate is more suited to situations involving long-term health and environmental issues than would be applied to more immediate transport user benefits. This scenario provides an opportunity to show the measurement effect of a lower discount rate, plus other adjustments, to acknowledge future value as deemed appropriate.[50] At this stage, it is recommended the alternative discount rate applied is as per the MBCM sensitivity recommendations; in time, consideration could be given to a customised approach. It is also possible that, eventually, the hierarchy of scenario 3 and scenario 4 will change.

An example of the recommended approach is described below:

1. A study area is identified as having proportionally more children.
2. The screening tool points to potential equity issues for children around severance, personal security, accessibility, traffic accidents, road safety, transport noise and transport fumes.

Table 3.5 summarises the measurements to undertake for the five scenarios. As shown, this requires a mix of measurement methods and will require judgements. It is expected the judgements needed for scenario 3 and scenario 4 can be standardised quickly and the methods used in scenario 2 will continue to evolve.

Chapter 4 provides further details on the measurement of the effects identified in Table 3.5.

[50] Choosing discount rates for transport investments needs further research. If a project delivers returns that can be reinvested at the same rate and risk profile as the project itself, the cost of capital is an appropriate discount rate. This discount rate should incorporate a market-based risk premium. However, the capital cost of the project must truly represent the opportunity cost of that capital used for other investment. A social rate of time preference is likely to be more appropriate if this is not the case.

Table 3.5 Measurements required to take into account children equity issues

Effect	Scenario 1 MBCM	Scenario 2a Other average WTP	Scenario 2b Local areas adjustment	Scenario 3 Income adjustment	Scenario 4 Time effect
Severance	No measure	No measure yet identified. Likely to involve WTA and WTP issues	None (because no measure available)	None (because no measure available)	None (because no measure available)
Personal security	No measure	Consider NMBM 1.2	Upscaled by proportion of children	Adjust for regressive effect	None. Benefits more immediate
Accessibility	No measure	Consider CBAx 207	None. Local effects likely already within measure	Adjust for regressive effect	None. Benefits more immediate
Traffic accidents	3.1 Death and serious injury	Adjust for income and declining risk tolerance over time	If high-risk area, adjust for higher WTP If increase in risk, consider WTA	Adjust for regressive effect	Apply lower rate due to health effects
Transport noise	3.5 Noise	None because likely immaterial	None because likely immaterial	None because likely immaterial	Apply lower rate due to health effects
Transport fumes	3.3 Emissions	None because likely immaterial	None because likely immaterial	None because likely immaterial	Apply lower rate due to health effects

Source: Principal Economics
Note: MBCM = Waka Kotahi monetised benefits and costs manual; NMBM = Waka Kotahi non-monetised benefit and cost manual; WTA = willingness to accept; WTP = willingness to pay.

3.3.3 Method C: Welfare weights

Method C is as shown in section 3.1. The discussion highlighted difficulties with both measuring and interpreting the results, including that there is no universal acceptance of the appropriate weights and decision-makers will have difficulty in understanding and comparing welfare-weighted net present values.

For these reasons, a standardised weighting process was incorporated into method B, as a way to introduce welfare weighting into the CBA process, in keeping with the advice of Brent (2006, p. 26).

3.3.4 Method D: Accessibility and enhanced-capability benefits

Method D has not been discussed above. While this methodology is still under development, we suggest it provides a useful equity assessment framework. This method also ties CBA more closely to (a) the capabilities approach of the LSF and (b) the accessibility measures that are increasingly being reported. We suggest further exploring the use of this method. In addition, the recent focus on accessibility as the outcome of transport intervention (instead of mobility) could provide further flexibility for using the outcome of an accessibility-based equity analysis with other assessments.[51]

[51] This is noted in Ministry of Transport (2017, p. 6):

> *Access is a complex three-way system that integrates our physical mobility (transport systems and infrastructure); our spatial proximities (how we use land); and our telecommunications (the use of technology and digital connectivity). An holistic approach to this triple-access system underpins economic activity, social participation and wellbeing.*

The assessment of inequity effects using accessibility outcomes is an emerging methodology. The use of accessibility has been further investigated by the International Transport Forum (ITF), which recommended:

> *[The] key benefit of adopting accessibility metrics is they enable a clearer focus on distributional issues than is feasible using traditional CBA. This includes the level of accessibility of particular groups, especially the disadvantaged. Presenting accessibility analysis in conjunction with the results of a broaden CBA will therefore significantly improve the information base available to decision makers.* (ITF, 2020, p. 6)

In New Zealand, Adli (2019) discussed the measurement of accessibility at the granular suburb level. Accordingly, the measured accessibility outcomes are linked to the socioeconomic features of residents (in those suburbs), providing an estimate of distributional effects. The most critical argument is around the measurement of the value of the provided accessibility for different socioeconomic groups. This requires a detailed assessment of WTP, which accounts for the revealed and unrevealed preferences. The reason for accounting for unrevealed preferences is that the analysis of WTP will be biased if it does not account for the WTP of those people located in areas with poor access to public transport. A precise estimation of WTP, together with estimates of changes in accessibility, provides a robust framework accounting for the supply and demand of public transport:

- On the supply side, it is required to estimate the changes in accessibility by different socioeconomic groups. The accessibility impacts of a project need to be estimated at granular geographic levels and linked to the socioeconomic features of households (for example, the income groups – the appropriate dimension of inequity to be considered further).
- On the demand side, the WTP of different socioeconomic groups for changes in accessibility needs to be estimated.

The available approaches and gaps in knowledge for implementing method D are discussed below.

3.3.4.1 Gaps and potential approaches for method D

On the supply side, method D involves the specification of both socioeconomic groups and measures of accessibility to be explicitly defined.

3.3.4.2 Identifying the socioeconomic groups

Some academic researchers have used composite spatial indicators as an alternative to specifying socioeconomic groups, when assessing transport accessibility. This includes research by Currie (2004), who specified a composite transport needs indicator based on a weighted index of household and individual features, and Nazari Adli and Donovan (2018), who adopted the NZDEP indicator of socioeconomic deprivation.

3.3.4.3 Measurement of accessibility

Currently, the MBCM adopts a mobility-based approach that is incompatible with accessibility-based measures. More recently, the GPS on land transport has set three measures of accessibility as indicators for the strategy of '[p]roviding people with better travel options to access places for earning, learning and participating in society' (New Zealand Government, 2020, p. 4). These three measures are: (a) access to jobs, (b) access to essential services (shopping, education and health facilities) and (c) percentage of the population with access to frequent public transport services.

It is widely acknowledged that the adoption of accessibility metrics provides greater insight into distributional issues beyond that of the traditional CBA, with academic researchers increasingly favouring its use over mobility-based measures (ITF, 2020). While consideration for accessibility has been included in national transport documents (such as the GPS),[52] it has not been formally adopted in the CBA processes.

Section 2.2.6 presents potential measures of accessibility. In New Zealand, researchers have often used spatial definitions for measures of accessibility. Regarding technical limitations, measurement of accessibility requires network analysis of how accessibility has changed for spatial units or individuals. Because most transport appraisals use a level of network analysis, we do not think the technical requirement will be a significant burden for this method.

While many metrics are available for accessibility, no dominant metric satisfies the criteria needed for widespread adoption (these include applicability, theoretical validity, ease of operation, communicability, use in economic appraisal, and use in equity evaluation). Geurs (2018) compared different accessibility metrics and their suitability for economic and social evaluation.

National accessibility measures in New Zealand are becoming increasingly available. Work undertaken by Waka Kotahi provides spatial datasets on access to public transport (within 500 metres of a stop with transport that runs every 30 minutes at scheduled morning peak, 2018), access to high frequency public transport (within 500 metres of a stop with transport that runs every 15 minutes at scheduled morning peak, 2018), and granular location-based accessibility datasets of the proportion of the population living within travel thresholds of 15, 30 and 45 minutes of education, health care and supermarkets at morning peak times for different travel modes (Waka Kotahi, 2021a).[53]

Along with the more common measures in New Zealand, we suggest further consideration of others. Van Wee (2016) noted the usefulness of the logsum measure because of its alignment with the CBA framework due to the inclusion of the utility of choice option. Also, van Wee (2016) suggests the logsum measure deals with changes in spatial distributions of origins and destinations and the choice options measured by multiple attributes of alternatives that can be included.

Given the recent focus in New Zealand policy documents on wellbeing outcomes, a consistent measurement of accessibility will be useful. A wellbeing-based approach would include the accessibility metric, to include the perception of accessibility or potential of accessibility even if an individual does not exercise the option (Guers, 2020).

3.3.4.4 Measurement of demand

After finding the appropriate measure of accessibility, it is critical to measure the value of accessibility for different socioeconomic groups. This requires a detailed assessment of WTP for different groups, which accounts for revealed and unrevealed preferences.

The available transport equity studies do not account for WTP. This is because they rely on Sen's capability approach (or a version of that) and argue that an equitable transport policy needs to provide access to all groups, without taking demand into consideration. We suggest a more useful approach would be to account for demand and the importance of accessibility to different socioeconomic groups. In particular, Stroombergen et al. (2021) studied the impact of accessibility in addressing mismatches between job locations and affordable housing in four urban study areas: Auckland, Napier–Hastings, Wellington and Dunedin. Their results suggest that '[g]reater accessibility to job opportunities tends to be associated with lower wages (net of commuting costs) and higher house prices. The effect varies in strength across gender

[52] 'Enabling all people to participate in society through access to social opportunities, such as work, education and healthcare.' (New Zealand Government, 2020, p. 14)

[53] Waka Kotahi – *Inclusive access: Access to key destinations storymap* https://storymaps.arcgis.com/collections/16be4050255c49489067a39bca090818?item=6

and worker skill. We failed to find a strong relationship between accessibility and employment rates, which we might expect if spatial mismatch were problematic' (Stroombergen et al., 2021, p. 8). This finding suggests that improving access may not necessarily lead to improved functioning for disadvantaged population groups, as assumed by the studies using method D.[54]

Nahmias-Biran and Shiftan (2016) used activity-based accessibility measures to determine the maximum utility of travellers. This was then converted to subjective wellbeing using the marginal utility of income, providing a comparable subjective value of accessibility.

In New Zealand, we do not identify any studies estimating the WTP for accessibility of different socioeconomic groups. An indicative WTP of different socioeconomic groups could be derived from linking the estimates of expenditure elasticity to income and accessibility levels of suburbs. Torshizian and Isack's (2020) study of WTP in Auckland provides expenditure elasticity estimates at granular suburb levels. The study accounts for the bias from the unavailability of public transport (as discussed above). The income information is available from the Census data, and the spatial accessibility measures could be constructed using spatial analysis, using the methods described in the Waka Kotahi research report 682 (Stroombergen et al., 2021).

3.3.4.5 Method D remains useful, but is currently inconsistent with the Waka Kotahi monetised benefits and costs manual's mobility-based approach

While method D is useful for assessing the distributional effects of transport projects, the lack of consistency with the current MBCM's mobility-based approach limits its usefulness for this study. We suggest the following steps are taken to improve the feasibility of this approach within an MBCM assessment:

1. Further investigating the usefulness of replacing the mobility-based assessment with an accessibility-based method in MBCM.
2. Analysing the available measures of accessibility and their relevance to policy targets, including resilience and wellbeing.
3. Analysing the WTP of different socioeconomic groups for improved accessibility using the identified measures.

3.4 Advantages and disadvantages of approaches

Method A and method C are as discussed in sections 3.3.1 and 3.3.3. Note, method A already follows the recommendation of other transport authorities (UK and Australia) around reporting distributional benefits although this is not widely applied, partly because of significant measurement challenges, which are discussed in section 3.5.

Method B is presented separately, partly to emphasise the role that sensitivity analysis could play and also because it provides an enhancement that does not rely on the measurements required in method D.

Otherwise, it is noted that equity fits more widely within the decision-making process, including much earlier than when a CBA is typically undertaken. Equity can be part of the objectives; it can be part of the strategic approach to transport policy in general (including determining investment portfolios); it is likely to be important within a programme business case; it can be part of a strategic case within a project business

[54] This needs further investigation. First, the study by Stroombergen et al. (2021) only focused on access to jobs. However, as the authors highlighted, only 16 percent of trips in New Zealand are to get to or from work. Second, the authors highlighted several data issues for future research. Third, the measurement of accessibility used in that study should be further considered, to include a wider range of outcomes as unrevealed preferences.

case; and it will often be part of an MCA. Also, given these links, it is likely to be part of the ultimate funding priority decision; see, for example, Shiftan et al. (2021).

Methods not taken any further in this report include:

- Welfare weights (method C) other than those above linked to income, because the empirical and theoretical support for such weights is still emerging and there is little international precedence to apply. These include adjusting WTP to account for such things as preference for redistribution in total and redistribution as in-kind transfers.
- Weights derived from excess tax costs, because the transactions costs are unlikely to generalise to specific project situations and, if they do, the analysis fits within the sensitivity analysis approach of method B.

Table 3.6 shows the four methods presented above against the criteria given in section 3.3. For each criterion, we score the methods from low (low suitability) to high (high suitability).

The main advantage of method A (status quo) over others is its fit with the MBCM process, because it is currently being used. Method A does not require significant changes to existing procedures and has increasingly been used overseas in assessing transport equity issues, supporting the transport investment decision-making process. As a generalised procedure for assessing equity impacts, the cost of analysis is relatively low, with data readily available for analysts to assess the primary market impacts of transport projects. Method A’s simplicity also allows for a standardised reporting methodology that can be clearly communicated to decision-makers and the public. The method’s ability to measure effects of target groups of interest is unclear because no empirical analyses have used the current method.

Method B (status quo plus scenarios) expands on method A, including sensitivity analysis to inform decision-makers on uncertainty related to potential equity impacts. It provides greater transparency than the status quo method by providing a range of potential outcomes. This transparency comes at a higher analysis cost and reduces this method’s overall fit with the MBCM process, by adding the additional complexity of having a range of outcomes to consider. Method B inherits all the other advantages of method A.

Method C (welfare weights) has a lower fit with the current MBCM process. While it has a high material impact on equity, the initial derivation of welfare weights comes at a high cost and is likely to be difficult to transparently measure and implement. Furthermore, empirical and theoretical support for method C is still emerging, with few examples of international use despite its inclusion in the UK’s Green Book (HM Treasury, 2020). Plus, communicating what outputs the welfare weights represent is difficult.

Method D’s (accessibility and capabilities) accessibility-derived WTP is conceptually related to the New Zealand Treasury’s LSF and is acknowledged by Waka Kotahi as an area for further investigation. However, the method presents a notable shift in the MBCM approach, from mobility-based to accessibility-based assessment. The method has potential to allow for granular measurement of accessibility impacts on specific target groups, but the materiality of effects is unknown. Assessment of accessibility for transport appraisal has been an emerging topic in recent years with agreement on its inclusion, but has yet to mature to a level to be directly recommended in CBA manuals. While it adds to the cost of appraisal, because large-scale projects also include detailed transport modelling, intermediate outputs may be reused for reducing the overall cost of implementation. Standardised national measures of accessibility (in New Zealand) are being developed but WTP for accessibility is a work in progress. Communication of outputs, particularly accessibility, is attractive for decision-makers, given its ability to be shared visually using thematic maps.

Table 3.6 Methods and criteria

Criteria	Method A: Status quo	Method B: Status quo plus sensitivity analysis	Method C: Welfare weights	Method D: Accessibility and capabilities
Fit with MBCM	**High**	**Medium/high**	**Low**	**Medium**
Use of the method elsewhere in the world	**High**	**Medium/high**	**Low/medium**	Further development in recent years, not yet included in CBA manuals
Materiality of equity effect expected	**Medium**	**Medium/high**	**High**	Unknown
Ability of the method to measure effects for target groups of interest in New Zealand	**Not transparent**	**Medium/high**	**Medium**	**High (potentially)**
Cost of analysis as a proxy for 'ease of analysis'	**High (ie low cost used as base)**	**Medium**	**Low**	**Medium/low**
Whether measurement occurs in the primary (transport) market or secondary markets	Primary	Primary	Primary	Primary
Data and/or model availability in New Zealand	**High**	**High**	**Low**	**Medium**
Ease of communication	**Medium/high**	**Medium/high**	**Low**	**Medium/high**

Source: Principal Economics
Note: CBA = cost–benefit analysis; MBCM = Waka Kotahi monetised benefits and costs manual.

3.4.1 Recommended approaches

Based on the discussion above, we suggest exploring method B further. Method B is recommended as the most practical and effective way to further consider distributional effects. It takes the current inputs into a CBA, applies judgement as to where total benefits may be sensitive to equity effects and undertakes further analysis to at least ensure the transport project is not unintentionally undermining equity.

However, it leaves open the issue of identifying and accounting for specific distributional effects that the analysis above might miss. This still requires the reporting of distributional effects, as per the status quo (method A). These distributional effects would require weighting outside of the CBA, possibly through an MCA process.

The major assistance this research project could make to this recommendation is to guide the screening process regarding when distributional reporting and/or sensitivity analysis is appropriate and to show, by example, the screening, analysis and reporting. This also creates the opportunity to highlight the consequences of different justice tests (for example, egalitarianism versus sufficientarianism).

3.5 Guidance on measurement and mitigation

3.5.1 Measurement

The measurements required within method B will vary, depending on the nature of the inequity.

The following steps are recommended to increase the consistency of methods and transparency of results:

i. Use a standard screening tool to identify key benefits and disbenefits that likely pertain to the proposed project (requires development).
ii. Produce a standard set of scenarios, including a ‘pure’ MBCM scenario 1 (available already).
iii. Use methods from the Waka Kotahi non-monetised benefit and cost manual and CBAx in scenario 2a, where available, to estimate benefits not currently listed in the MBCM (requires development).
iv. Develop standard parameter values for adjustments to the WTP for different groups, to be applied in scenario 2b (requires development).
v. Apply a prescribed adjustment to the WTP for each national quintile group in scenario 3 (requires development).
vi. Apply a prescribed lower discount rate, as per the current MBCM, in scenario 4 (available already).

A screening tool in (i) can be developed relatively quickly, based on the tool currently used by the DfT.

Likewise, the welfare weights to apply in (v) can be developed from the DfT approach. This requires the selection of an elasticity parameter that suits the purposes of the wider decision-making process, that is, judgement is needed but at least like-for-like comparisons will be possible.

The most challenging measurements will be those for (iii) and (iv), given that measurements of many inequity effects have not been universally established. It is expected that measurement methods will be progressively put forward and refined, either led by Waka Kotahi research or the requirements of specific projects. The initial priority is to establish the materiality of key inequity effects.

3.5.2 Mitigation

This chapter has focused on providing a methodology to both measure and progressively improve measures of equity effects to be included in a CBA.

Disproportionate benefits (or even disbenefits) will almost always occur across groupings of people, and sometimes this disproportion may be considered inequitable. Several responses can be used in such situations, with only the first excluding mitigation:

1. accept the inequities
2. accept the inequities within the project on the understanding they will be rebalanced across a portfolio of transport projects
3. accept the inequities within the project on the understanding they will be compensated through wider income transfer processes
4. choose an alternative project
5. restart the business case to radically adjust the proposed project
6. refine the current project to remove or reduce the cause of the inequity.

The last mitigation – refining the project – can occur in multiple ways, depending on the inequity. Most likely, the major adjustments to a project design have been made at an earlier stage of the business case.

4 Applying the preferred method

This chapter identifies and quantifies the distributional effects by using the preferred method identified in chapter 3. The chapter provides a step-by-step guideline for analysis of distributional effects. To provide further details on implementing the required steps, we use our preferred case study for this project, which is the Auckland Transport Alignment Project (ATAP) 2021–2031.

The chapter starts by describing the process for choosing a case study and details are given on the preferred case study. We describe the data and methodology used for the step-by-step distributional impact analysis, including information about the transport modelling outputs of our case study. This is followed by details on the assessment of distributional impacts of our case study. The chapter finishes with information about the outputs of our sensitivity analysis and a summary of our findings from the case study.

Our distributional analysis outputs could be used as an input in an MCA or any other prioritisation tool. For further discussion on the complementary role of CBA and MCA, see section 2.4.5.

4.1 Case study: Auckland Transport Alignment Project 2021–2031

In our discussions with the Steering Group for this project, we identified the criteria below for selecting the appropriate case study for this project:

- Involves a range of people who benefit from the transport project
- The benefit varies in a non-random way between groups of people
- We can take measurements that enable the relevant groups of people to be measured
- We have some method that links the transport benefits to each group
- Preference for project with current issues.

We also gathered a list of projects, based on data availability, and asked for input from the Steering Group on the available case studies. The outcome, using the identified criteria, suggested that the ATAP 2021–2031 set of projects was an appropriate choice. However, it was also not possible in the time available to analyse the full effects of these projects. It is important to note, however, the benefits and disbenefits calculated and discussed are presented to show methodology and do NOT represent the full effects of 10 years of projects within the ATAP.

4.1.1 Auckland Transport Alignment Project 2021–2031 investments

ATAP 2021–2031 will involve around $31.4 billion being invested into critical transport infrastructure and services across Auckland. The project focuses on encouraging a shift from private cars to public transport, walking and cycling, and addressing Auckland’s longer-term challenges of climate change and housing development (Ministry of Transport, 2020). Investment in public transport, walking and cycling is significant, and further development of Auckland’s rapid transit network represents the largest area of investment in new infrastructure. Important programmes to improve bus priority, walking and cycling will also help support the mode shift.

A map of the projects planned for delivery by 2031 is given in Appendix D. ATAP 2021–2031 includes $13.6 billion of investment in operating, maintaining and renewing existing infrastructure and services, and $17.8 billion for new infrastructure (Ministry of Transport, 2021). Table 4.1 lists the key projects in ATAP 2021–2031.

Table 4.1 Key projects in the Auckland Transport Alignment Project 2021–2031

Key projects
City Rail Link and associated wider network improvements
Auckland Light Rail
Eastern Busway (Panmure to Botany)
Rail electrification to Pukekohe and delivery of third main rail line (Westfield to Wiri)
New electric trains
City centre bus improvements
Northwest interim bus improvements
Puhoi to Warkworth motorway
Northern Corridor improvements (including busway extension to Albany)
Papakura to Drury South motorway upgrade
Mill Road
Penlink
Significant programme of safety improvements
Connected Communities programme of bus priority, cycling and safety improvements

Source: Adapted from Ministry of Transport (2021, p. 9)

The projects included in our analysis of the ATAP cover a slightly smaller range of the ATAP and Regional Land Transport Plan investment package (with a value of $31.4 billion). The main projects excluded from our analysis are as follows:

- Northern Pathway (Westhaven to Akoranga), with a funding allocation of $360 million
- Safety improvements and safety projects, with a funding allocation of $892 million
- Walking and Cycling Programme, with a funding allocation of $1.5 billion
- Network optimisation and technology, with a funding allocation of $700 million
- Community Connect, with a funding allocation of $33 million.

When these amounts are subtracted from the $17.8 billion for new infrastructure, the total for new infrastructure investment included in the ATAP projects investigated in our analysis is $14.3 billion. For more details, see Ministry of Transport (2021).

4.2 Description of data and methodology

Data for our analysis were provided by Auckland Transport's Forecasting Centre. The data included the outputs of the passenger flow model as follows:

- outputs from the macro strategic model (MSM) run by the Auckland Forecasting Centre
- public transport matrices, zone information plots (accessibility and public transport patronage).

Accordingly, trips are modelled between 596 zones. The information is available for both the Do Nothing and 2031 ATAP scenario.

Stats NZ Census 2018 data provided information on the socioeconomic factors, including age group, income level, household composition, disability, ethnicity, motor vehicle access and dependant children.

Socioeconomic factors are allocated to the 596 zones based on their overlap with Stats NZ's statistical area 1 (SA1) and statistical area 2 (SA2) geographic units, depending on the granularity of data available.

For the disaggregation of outputs across income groups, we could use information available on income bands and the NZDEP index or score. The use of the NZDEP measure includes information on a range of factors of deprivation. We decided to use the income bands because the information provided would be clearer and solely related to income groups. However, the NZDEP measures remain useful for reporting the outputs of distributional analysis.

For the distributional analysis, we investigated the impacts on households and therefore used household income groups to disaggregate the impacts across income groups. This also meant the most granular level of our analysis is the household level, so we present the number of households (and not individuals) in our result tables.

Because no detailed business case was available for the ATAP, an initial step (Step 0) for our analysis is to assess the consumer surplus, consisting of the value of time savings from ATAP initiatives to users and non-users of public transport and private vehicles. The impacts are identified for home-based work, home-based education and employers' businesses. We also identify impacts for AM peak, inter-peak and PM peak times. Any wider range of impacts is beyond the scope of our consumer surplus analysis. This includes any impacts of travels outside the Auckland region and other trip types within the region.

4.2.1 Methodology for estimating impacts of the Auckland Transport Alignment Project

As noted, ATAP is an extensive programme of projects across the Auckland region. Our analysis timeframe does not allow us to provide a comprehensive (detailed) assessment of the benefits of the 2021–2031 ATAP investments. Our assessment, therefore, accounts for the most important impacts, in terms of magnitude. While a full assessment always provides more information, we suggest our assessment of the ATAP provides sufficient information for the purpose of our study, which is to show the distributional effects using the preferred methodology. We provide further details below on the distributional impacts of the ATAP investments and the benefits and disbenefits modelled.

Regarding the geographic granularity of our assessment, because we do not have the details for individuals, we are restricted to distributional effects that coincide with Stats NZ's SA2 geographic level origin areas.

Four modes of transport are included: light passenger-vehicle, public transport, active and medium vehicles, and heavy commercial vehicles. The outputs of transport modelling of the ATAP available to us provided information about light vehicles and public transport, so our analysis does not include any benefits to active mode and heavy commercial vehicles. Considering the range of projects included in the ATAP, we suggest that public transport and light passenger vehicle modes capture most of the benefits of the ATAP.

The MSM contains information on six trip purposes: home-based work (HBW), home-based education (HBE), home-based shopping, home-based other, employers' business, and non-home-based other. We limited our assessment of the impact of the ATAP to HBW and HBE, for two reasons: (a) it is reasonable to associate the benefits of these trips with the local residents and we have aggregate measures for zones, and (b) HBW and HBE are likely capture most of the impacts of the ATAP investments.

In the MSM, trip-ends and distribution mode split are 24-hour models, and 24-hour demands are split into five periods by the time-of-day choice model, as follows:

- AM peak (AM): 7 am to 9 am
- Interpeak (IP): 9 am to 3 pm
- School peak (SP): 3 pm to 4 pm

- PM peak (PM): 4 pm to 6 pm
- Off peak (OP): 6 pm to 7 am.

In our analysis, we consider the impacts at all the periods above. For IP, SP and OP periods, we do not know if the benefits are accrued to the origin or the destination, so it is unclear which population groups benefit. Because all the HBW trips either start or end at home, we assume all AM origins and their PM destinations relate to their place of residence (that is, passengers leave for work in the AM and return home in the PM). We calculated the total IP, SP, OP benefits, then took the ratio of HBW IP/SP/OP-to-AM/PM benefits and applied this ratio to the zone, to derive the total HBW benefits for each zone. Similarly, for HBE trips, we assumed all AM origins, SP and PM destinations relate to their place of residence (that is, they leave for school in the AM and return home in the PM or SP). We used the HBE, IP and OP benefits, and took the ratio of HBE IP/OP-to-AM/PM/SP benefits and applied this ratio to the zone to derive the total HBE benefits.

Based on the description of the information available on geographic granularity (available at SA2), the purpose of the trip, and timing of travel, we needed to identify the features of socioeconomic groups that would benefit from the impacts of the ATAP. For example, for the distributional analysis of the HBW trips during PM, we consider benefits to the population located at the destination.

For our analysis of the impact of the ATAP, we assessed the impacts over 40 years, during 2021–2061. The counterfactual scenario is the Do Nothing scenario in 2031. One limitation of our analysis is unavailability of data on the changes in socioeconomic features over time. We assumed, therefore, the distribution of socioeconomic features across suburbs would remain at Census 2018 levels. We discuss this limitation in section 5.3. For the population forecasts, we use the Auckland Council Land Use Scenario i11.6 population projections that have been used as an input to the MSM.[55]

An important caveat of our analysis is that we do not account for the impacts on new public transport users in the areas where public transport would not have been available under the Do Nothing scenario. This is because of a lack of information for calculating the changes in generalised costs and the short timeframe for our analysis. We suggest this caveat will have an effect on our findings in the south of Auckland areas.

Appendix F lists outputs of the MSM that we have used for the distributional analysis.

4.2.2 Methodology for distributional analysis

In the analysis, we need to consider both the beneficial and adverse distributional impacts of transport interventions and identify the social groups likely to be affected. We use the following steps to do this:

1. Screening process: This provides information on the likely impacts for each indicator.
2. Assessment of the impacts: Includes confirming the area(s) affected by the intervention (impact area), identifying the social groups and amenities in the impact area.
3. Appraisal of impacts: Includes the main analysis of the impacts.
4. Sensitivity analysis, including the other average WTP, local area adjustments, income adjustments and time effect.

We describe each step in the following paragraphs and use the ATAP case study to explain the analysis required.

[55] This scenario is Auckland Council's Land Use Scenario v i11.6, which covers the period 2018–2051.

4.2.2.1 Screening process (step 1)

The process is similar to that described in Table 3.4 in section 3.3.1. The following 10 indicators identified for inclusion in the distributional impact analysis are shown in Table 4.2. The first step (screening process) identifies the potential impact of the intervention (ATAP). For each indicator, we include a suggested appraisal output criteria in column (a). Then, column (b) provides information on the potential impact and its sign. In column (c), we provide an explanation on the qualitative impact assessment provided in column (b). Finally, column (d) shows whether we should further progress with the distributional analysis of each indicator.

Table 4.2 Indicator screening

Indicator	(a) Appraisal output criteria	(b) Potential impact (yes/no, positive/ negative if known)	(c) Qualitative comments	(d) Proceed to step 2
User benefits	The user benefit analysis has been used in the appraisal.	Yes, positive.	High levels of congestion in Auckland have a large effect on journey time. Auckland Transport Alignment Project (ATAP) will reduce journey time for through-traffic and provide benefits across the region. The higher speed travelled may have a negative effect on vehicle operating costs, but this is likely to be lower than the positive effect on time costs.	Yes, distribution of benefits across different areas will need to be examined.
Air quality	Any change in alignment of transport corridor or links with significant changes in vehicle flow, speed or percentage of heavy duty vehicles (HDVs) content: • Change in 24-hour annual average daily traffic (AADT) of 1,000 vehicles or more • Change in 24-hour AADT of HDVs of 200 HDVs vehicles or more • Change in daily average speed of 10 kilometres per hour or more • Change in peak hour speed • Change in road alignment of 5 metres or more.	No, neutral.	ATAP focuses on encouraging the shift from private cars to public transport, walking and cycling, and addressing Auckland's longer-term challenges of climate change and housing development (Ministry of Transport, 2020). Given the range of projects across the region and the less (geographic) granularity of air quality outcomes, it is likely the impacts are distributed equally.	No.
Accidents	Any change in alignment of transport corridor (or road layout) that may have positive or negative safety impacts, or any links with significant changes in vehicle flow, speed, %heavy goods vehicle (HGV) content or any significant change (more than 10%) in the number of pedestrians, cyclists or motorcyclists using road network.	Yes, positive.	ATAP provides a range of improvements in the transport network. This will likely have a positive effect across the region, with some suburbs and socioeconomic groups benefiting more than others.	Yes.

Indicator	(a) Appraisal output criteria	(b) Potential impact (yes/no, positive/ negative if known)	(c) Qualitative comments	(d) Proceed to step 2
Security	Any change in public transport waiting and/or interchange facilities, including pedestrian access, is expected to affect user perceptions of personal security.	Yes, positive.	The outputs of the ATAP will likely improve active mode and the perception of personal security.	Yes.
Severance	Introduction or removal of barriers to pedestrian movement, either through changes to road crossing provision or the introduction of new public transport or road corridors. Any areas with significant changes (more than 10%) in vehicle flow, speed, %HGV content.	Yes, mixed.	The traffic redistribution of the ATAP will likely have mixed effects across suburbs, with most experiencing improved traffic flow near the new routes, while other suburbs experience increases in congestion due to traffic redistribution.	Yes.
Accessibility	Changes in routings or timings of current public transport services, any changes to public transport provision, including routing, frequencies, waiting facilities (bus stops and rail stations) and rolling stock, or any indirect effects on accessibility to services (eg demolition and relocation of a school).	Yes, positive.	ATAP provides a range of transport options across Auckland suburbs, which will improve accessibility to job location and other activities.	Yes.
Labour market deepening	In case of improvements in accessibility, the impacts on job matching need to be investigated further.	Yes, positive.	ATAP provides a range of travel options to and from employment centres. This will likely improve outputs of job search.	Yes.
Social cohesion	In cases where a significant change occurs in the distribution of businesses and households across suburbs, further investigation of the impact on sense of belonging is recommended.	Yes, mixed.	Various areas have high concentrations of ethnic groups affected by the ATAP. This will likely lead to changes in people's sense of belonging and connectedness to the local community.	Yes.
Affordability	In cases where the following costs would occur: parking charges (including where changes in the allocation of free or reduced-fee spaces may occur); car fuel and non-fuel operating costs (where, for example, rerouting or changes in journey speeds and congestion occur resulting in changes in costs); road user charges (including discounts and exemptions for different groups of travellers); public transport fare changes (where, for example, premium fares are set on new or existing modes or where multi-modal discounted travel tickets	Yes, positive.	ATAP is associated with lower public transport fares and potential changes in vehicle operating costs (VOC). The effects are mixed across the region, given the higher VOC from increase in speed and the lower public transport fares. Overall, the effects are positive, but it is useful to provide information on their distribution across socioeconomic groups.	Yes.

Indicator	(a) Appraisal output criteria	(b) Potential impact (yes/no, positive/ negative if known)	(c) Qualitative comments	(d) Proceed to step 2
	become available due to new ticketing technologies); or public transport concession availability (where, for example, concession arrangements vary because of a move in service provision from bus to light rail or heavy rail, where such concession entitlement is not maintained by the local authority).			
Noise	Any change in alignment of transport corridor or any links with significant changes (more than 25% or less than –20%) in vehicle flow, speed or percentage of HDV content.	Yes, mixed.	ATAP has an overall positive impact for noise, because a lot of traffic will move further away from residential areas, and a mode shift will occur to active modes. Many roads in the area will see a change in traffic volumes and noise levels: some positive and some negative.	Yes.

Source: Principal Economics, adapted from DfT (2020a) and Geurs (2018)

4.2.2.2 Assessment of the impacts (step 2)

Step 2 further refines the impact area and social groups affected by the intervention. The broad impact areas identified in step 1 (screening) are examined further to identify the specific areas relevant to the distributional impact analysis. Given the range of projects in the ATAP programme, we consider all of the 596 zones included in our analysis, providing information across all transport zones fitting within the Auckland footprint.

To identify the social groups in the impact area, we consider the social and demographic features of the population. For this, we consider:

- transport users who will experience changes in generalised travel costs resulting from the intervention
- people living in areas who may experience impacts of the intervention, even if they are not users
- people travelling in areas identified as likely to be affected by the intervention.

Analysis of the characteristics of transport users is based on their likely features, as identified from the percentage of social groups in the origin of the travel.

Analysis of the characteristics of people living in the area is informed by mapping social characteristics of interest at the transport zones provided in our transport matrices.[56] The groups to be identified in the analysis for each indicator are shown in Table 4.3. At this stage, it is important to investigate impacts for all indicators and socioeconomic groups. A tick indicates the distributional analysis required for each impact. For example, if the only distributional impact identified within the scope is the user benefits, then it is necessary to prepare mapping of the proportions of income groups, children, and households with dependant children.

[56] The features of the population groups provided in Stats NZ's 2018 Census are mapped to the boundaries of the transport zones, which are broadly consistent with aggregations of Stats NZ's geographic units. Where the transport zones do not perfectly align with Stats NZ's area boundaries, the population counts are proportionally allocated to the area extent of geospatial overlap.

Table 4.3 Scope of socioeconomic analysis

Social group	User benefits	Air quality	Accidents	Security	Severance	Accessibility	Labour market deepening	Social cohesion	Affordability	Noise
Household income distribution	✓	✓				✓	✓		✓	✓
Children: aged under 16 years	✓	✓	✓	✓	✓	✓				✓
Young adults: aged 16 to 24 years			✓			✓	✓			
Older people: aged 70-plus years			✓	✓	✓	✓		✓	✓	
Population with a disability				✓		✓	✓	✓		
Population of minority ethnic origin				✓	✓	✓	✓			
Households without access to a car					✓	✓	✓			
Households with dependant children	✓	✓	✓	✓	✓	✓	✓	✓		✓

Source: Principal Economics

Identifying amenities in the impact area

The concentration of socioeconomic groups is based on resident population and the trip attractors (amenities) located within the impact area. For example, the overall proportion of children in the impact area may not be high, but if a school is located within the area, then children are likely to be travelling within the area and so are considered within the assessment. We suggest identifying the local amenities likely to be used by the identified social groups, for each indicator. This amenity data provides more context for qualitative assessments, in addition to the distributional analysis, and provides a wider assessment than just that of the resident population.

Because the impact area of our case study is the Auckland region,[57] it is difficult to consider amenities in our qualitative assessment because of the wide range available. For the studies with smaller impact areas, however, we suggest considering the amenities for each indicator, as presented in Table 4.4. Along with the listed amenities, other amenities, such as shops and cafes, could be considered in the analysis.

[57] While the macro strategic model (MSM) includes travel to areas outside of the Auckland region, we have excluded them from this analysis because we did not have access to spatial information about the transport zones outside Auckland. Additionally, the extent of Auckland transport zones identified in the MSM extends the boundaries of Auckland in the suburbs of Pokeno and Tuakau. We account for this in our reported figures using Census 2018.

Table 4.4 Amenities within the impact area (example)

Amenities presented	User benefits	Air quality	Accidents	Security	Severance	Accessibility	Labour market deepening	Social cohesion	Affordability	Noise
Schools and nurseries		✓	✓	✓	✓	✓				✓
Playgrounds		✓	✓	✓	✓	✓				✓
Parks and open spaces		✓	✓			✓		✓		✓
Hospitals			✓			✓				
Care homes			✓	✓		✓				
Community centre			✓			✓		✓		

Source: Principal Economics inspired by DfT (2020a, p. 12)

After identifying the scope of the socioeconomic analysis (Table 4.3 and Table 4.4), we use the available data to provide an outputs summary of our assessment, see Table 4.5. Because the impact area is the whole Auckland footprint, we identified New Zealand as the relevant comparison group (as shown in the last column of the table). Because we do not disaggregate population groups for the identified amenities, the variations presented in Table 4.5 are small. The figures in Table 4.5 provide information on the percentage of net benefits for each income group. For accessibility and affordability, the figures are different because we are not able to estimate the dollar values for net benefits.

Table 4.5 Social group summary (% of population)

Social group		User benefits	Air quality	Accidents	Security	Severance	Accessibility	Labour market deepening	Social cohesion	Affordability	Noise	Auckland*	New Zealand
Household income groups	(1) $1–$30,000	15.35	?	15.85			15.52	?		15.52	?	15.42	18.82
	(2) $30,000–$70,000	22.70	?	22.55			22.71	?		22.88	?	22.85	28.16
	(3) $70,000–$100,000	14.73	?	14.62			14.68	?		14.70	?	14.71	15.87
	(4) $100,000–150,000	21.47	?	20.66			21.05	?		21.02	?	21.06	19.33
	(5) $150,000 or more	25.75	?	26.31			26.04	?		25.88	?	25.95	17.83
Children: Under 15 years		20.65	?	19.17	?	?	19.61			17.13	?	19.97	19.65
Young adult: Aged 15–24 years				15.06			14.53	?		12.60		14.23	13.18
Elderly: Over 70 years				8.50	?	?	7.90	?	?	7.13		8.09	10.34
Population with a disability†		10.12	?	9.74	?		9.99		?	8.79		9.54	10.82
Ethnic distribution	Māori	13.23	?	10.92	?	?	11.25	?		9.87		11.53	16.51
	Pacific peoples	12.41	?	13.52			15.50			13.87		15.52	8.12
Households without access to a car						?	7.18	?		6.17		6.59	6.61
Households with dependant children		40.09	?	37.99	?	?	39.23	?	?	34.01	?	38.09	33.18

Source: Principal Economics

Note: Question marks (?) represent a lack of information for undertaking the distributional analysis, as discussed in the next sections.

The percentages reported for user benefits and accidents in Table 4.5 show the magnitude of distribution across the identified social groups. Because we have not identified a method for quantifying a dollar value for accessibility and affordability improvements, the percentages reported for accessibility and affordability impacts are based on the number of individuals and/or households affected.

* Our reported figures for Auckland socioeconomic figures are consistent with Stats NZ's definition of the Auckland region and exclude the suburbs of Pokeno and Tuakau.

† We included all individuals who responded that they were unable to or had considerable difficulty in completing the Washing Group Short Set on Functioning as part of the Stats NZ Census 2018. We used the total number of responses in all groups, so the results may overestimate the number of individuals in cases where they experience multiple disabilities.

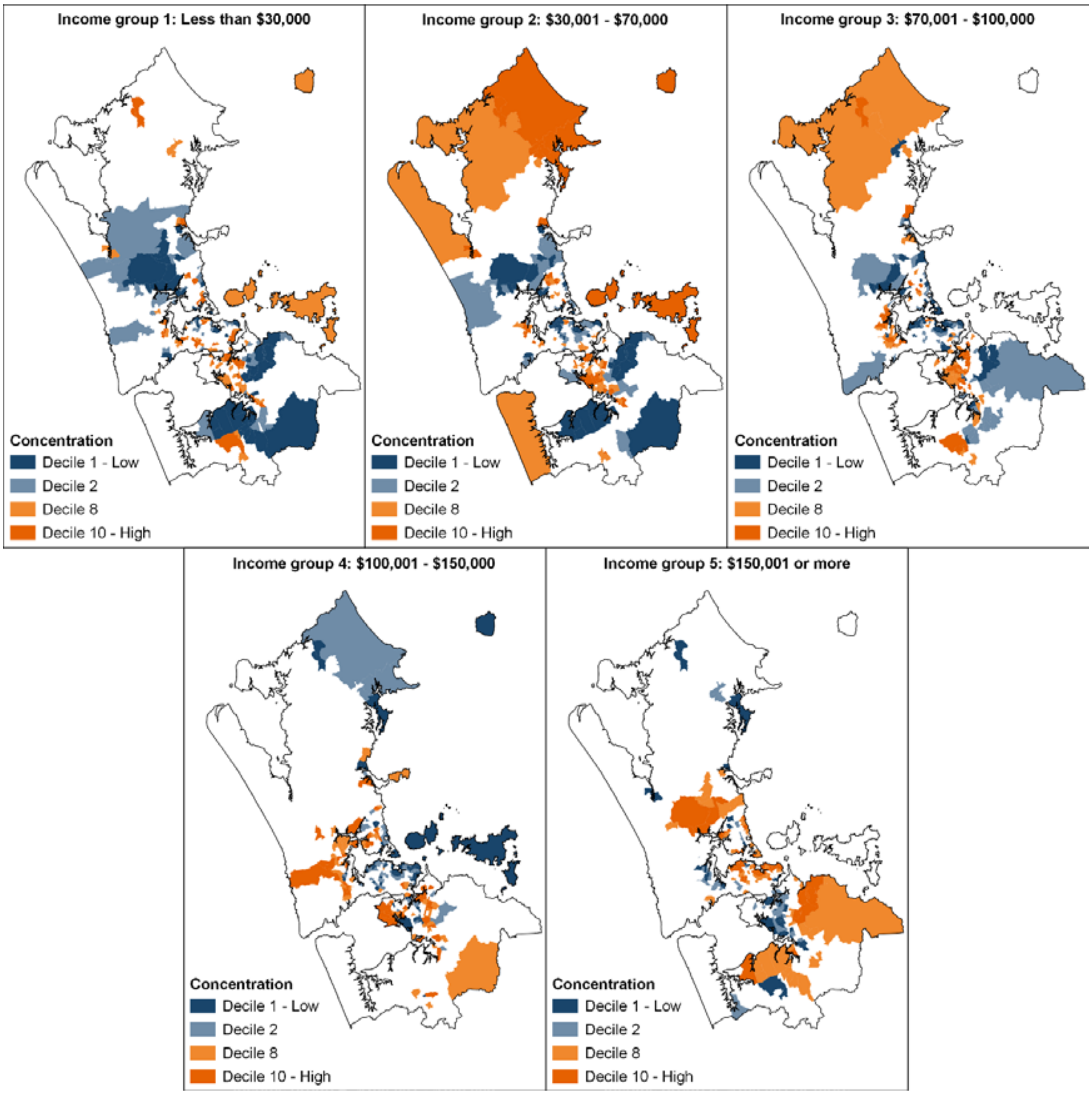
Limitation of our assessment of impacts

Table 4.3 identifies the various proportions that would be ideal to be identified for each impact. However, the range of impacts in Table 4.3 is wider than the information we could collect at the time of this research project. This is discussed in section 4.3 and section 5.1.

Mapping of socioeconomic groups

We mapped the socioeconomic features of vulnerable groups in the impact area in Figures 4.1 to 4.4. As shown, the transport zones (in the impact area) have significant *concentrations*[58] of income groups, ethnic groups, different age groups and other relevant socioeconomic features. This grouping of people increases the chance of significant distributional effects.

Figure 4.1 Distribution of income groups in the impact area

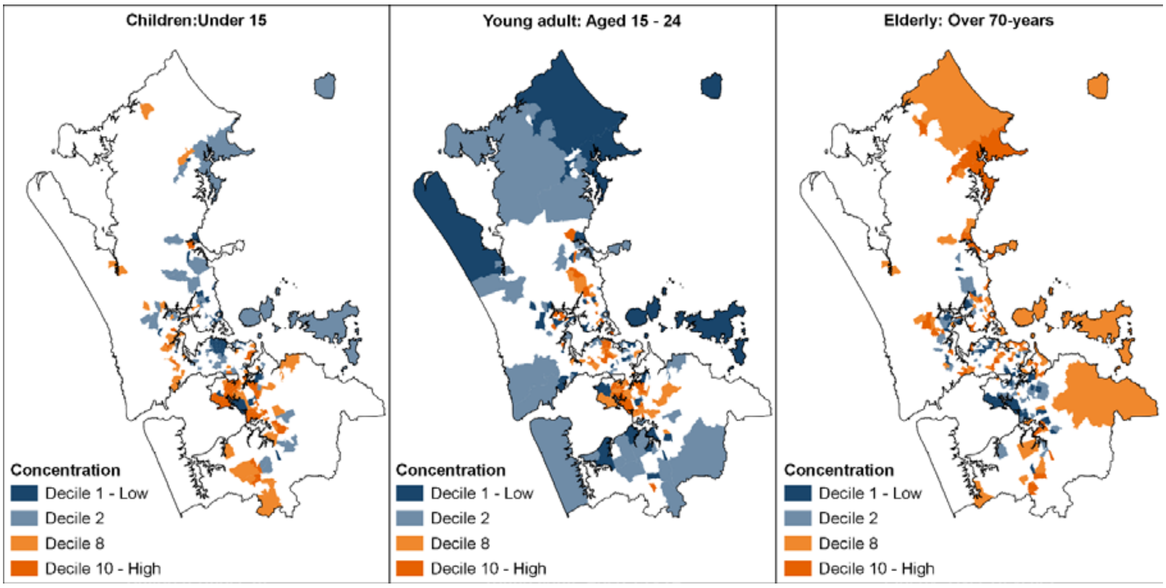


Source: Stats NZ Census 2018

Note: Income groups are based on Census 2018 total household income at statistical area 2 (SA2) geographic levels. We have attempted to match the household income quintiles reported in the Stats NZ Household Economic Survey by aggregating household income data publicly available for the Census 2018. This information is spatially mapped to transport zones for reporting and assessment. Where SA2 geographic units do not align with transport zones, we distributed household counts on a pro rata basis according to land area. Concentration deciles are based on the proportion of each income group that reside within transport zones; so, for Income Group 1, transport zones identified as having a Decile 10 concentration consist of 22.8 percent of households having an income of less than $30,000 per annum.

[58] While distributions of all deciles provide useful information, it is useful to focus on spatial concentrations of the upper and lower socioeconomic groups to focus further on the most vulnerable groups.

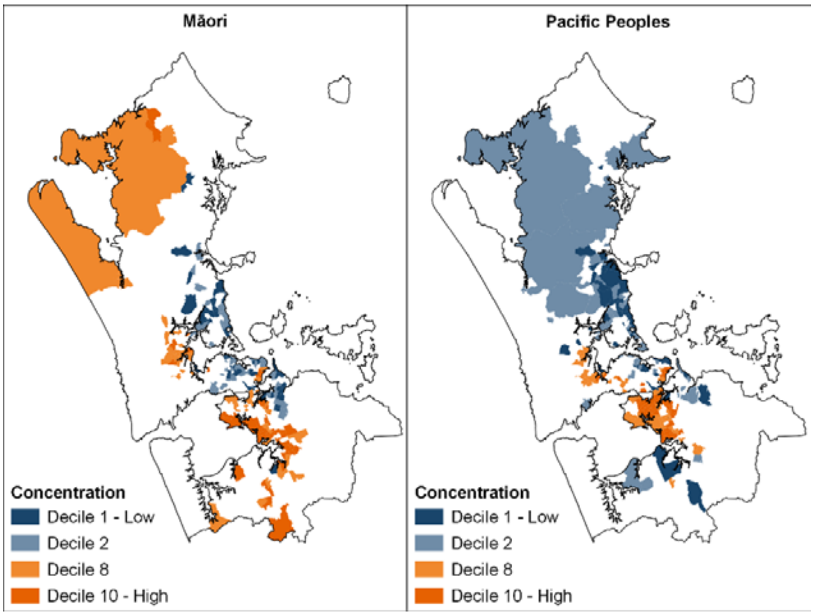
Figure 4.2 Distribution of age groups in the impact area



Source: Stats NZ Census 2018

Note: Age groups are based on the Census 2018 statistical area 1 (SA1) geographic datasets and aggregate more granular population age brackets to the relevant age groups. This information is spatially mapped to transport zones for reporting and assessment. Where SA1 geographic units do not align with transport zones, we distributed household counts based on a pro rata basis according to land area. Concentration deciles are based on the proportion of each age group that reside within transport zones. For example, for children under 15, transport zones identified as having a Decile 10 concentration consist of 25.4 percent of the zone population being under 15 years of age.

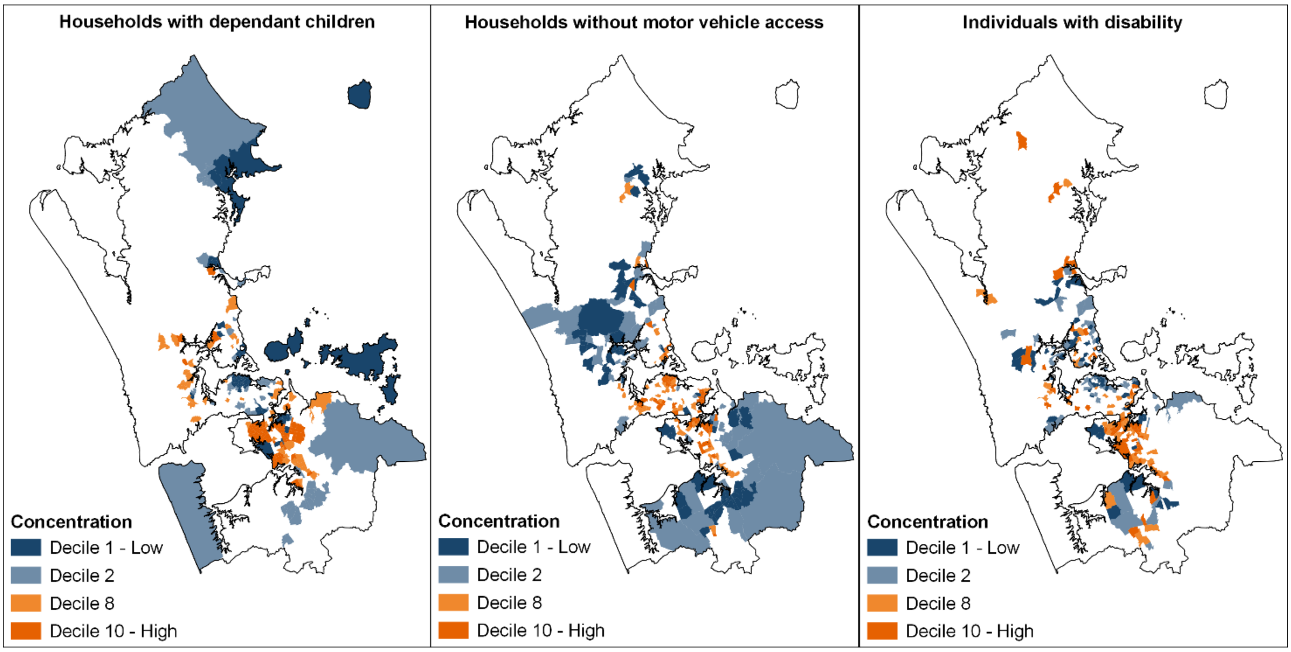
Figure 4.3 Distribution of ethnic groups in the impact area



Source: Stats NZ Census 2018

Note: Ethnic groups are based on the Census 2018 statistical area 1 (SA1) geographic datasets. This information is spatially mapped to transport zones for reporting and assessment. Where SA1 geographic units do not align with transport zones, we distributed household counts based on a pro rata basis according to land area. Concentration deciles are based on the proportion of each ethnic group that reside within transport zones. For example, for children under 15, transport zones identified as having a Decile 10 concentration represent 21.4 percent of the zone population identified as being of Māori ethnicity. Additionally, we note that individuals can identify as more than one ethnicity, so a person may be counted in more than one group.

Figure 4.4 Other relevant socioeconomic groups in the impact area



Source: Stats NZ Census 2018

Note: Households with dependant children are based on the Census 2018 statistical area 2 (SA2) geographic datasets, while households without motor vehicle access and individuals with disability are based on SA1 level Census 2018 datasets. This is because not all data from the Census 2018 are available at the more granular SA1 geographic level (this is generally occurring for classifications that require further analysis by Stats NZ beyond the Census response choices). Where possible, we have attempted to use more granular information, where it is publicly available. This information is spatially mapped to transport zones for reporting and assessment. Where statistical area 1 (SA1) and SA2 geographic units do not align with transport zones, we distributed household counts based on a pro rata basis according to land area. Concentration deciles are based on the proportion of each group that resides within transport zones. For example, for households with dependant children, transport zones identified as having a Decile 10 concentration consist of 49.8 percent of the zone.

For individuals with disability, we included all those who responded to the capability questions in the Census 2018, based on the Washing Short Set on Functioning[59] as having 'a lot of difficulty' or 'cannot do at all'. We included responses from all five questions relating to a person's difficulties in communicating, hearing, remembering or concentration, seeing, walking or climbing steps, and self-care such as washing all over or dressing. A person may, therefore, be counted more than once if they identify as having multiple disabilities.

4.2.2.3 Appraisal of impacts (step 3)

After screening and identifying the impact area and socioeconomic groups, in the third step we assess the effect of the intervention on each indicator's social groups for input into the appraisal summary table.

The first step in the appraisal of impacts is to grade the significance of the benefits to each of the identified social groups. We suggest the grading system shown in Table 4.6. We use these symbols in the assessment tables for each indicator, to show the distribution of impacts across income groups. We provide a criterion for defining the number of ticks based on the sign of overall net benefits and the deviation of the distribution of net benefits across each income group from its average. For example, if income group 1 has a 20 percent share of the population and its share of net benefits is 22 percent, then the difference between that income group's net benefits from its share of population is equal to 2 percent. Assuming the standard deviation of

[59] See www.washingtongroup-disability.com/fileadmin/uploads/wg/Documents/Washington_Group_Questionnaire__1_-_WG_Short_Set_on_Functioning.pdf, for further information.

the difference between income groups' net benefits from their population share is equal to 1.2, then income group 1's difference from mean is larger than one standard deviation. That suggests income group 1 should receive either three ticks if its net benefit (✓✓✓) is positive and three crosses (×××) if its net benefit is negative.

Table 4.6 Assessing the importance of impacts

Impact	Criteria	Assessment (symbol)
The cohort's share of **benefits** exceeds the cohort's share of population	Net benefits are positive and the difference between the distribution of net benefits and an income group's share of population is greater than one standard deviation of that difference	Large beneficial (✓✓✓)
The cohort's share of **benefits** is broadly similar the cohort's share of population	Net benefits are positive and the difference between the distribution of net benefits and an income group's share of population fall within one standard deviation of that difference	Moderate beneficial (✓✓)
The cohort's share of **benefits** is smaller than the cohort's share of population	Net benefits are positive and the difference between the distribution of net benefits and an income group's share of population is smaller than one standard deviation of that difference	Slight beneficial (✓)
No significant benefits or disbenefits are experienced by the cohort for the specified impact	Net benefits are zero	Neutral
The cohort's share of **disbenefits** is smaller than the cohort's share of population	Net benefits are negative and the difference between the distribution of net benefits and an income group's share of population is smaller than one standard deviation away from the mean	Slightly adverse (×)
The cohort's share of **disbenefits** is broadly similar the cohort's share of population	Net benefits are negative and the difference between the distribution of net benefits and an income group's share of population falls within one standard deviation of that difference	Moderate adverse (××)
The cohort's share of **disbenefits** exceeds the cohort's share of population	Net benefits are positive and the difference between the distribution of net benefits and an income group's share of population is greater than one standard deviation above the mean	Large adverse (×××)

Source: Principal Economics inspired by DfT (2020a, p. 13)

Using the grading system in Table 4.6, we grade each indicator and each social group. In Table 4.7, we undertake a qualitative assessment for each indicator describing the main impacts in each case. The indicators in the table are those identified in Table 4.3, with importance to the distribution of income. We have not included the indicators that we decided to not pursue further in the first step (the screening process).

Table 4.7 Distributional impact appraisal matrix – income distribution

	Income groups					Impacts distributed evenly?	Qualitative notes
	Income group 1	Income group 2	Income group 3	Income group 4	Income group 5		
User benefits	✓✓✓	✓✓	✓	✓✓	✓✓✓	No	All income groups benefit from the outcomes, but the benefits are not distributed equally. It is likely those in the highest and lowest income groups benefit more than the other income groups.
Air quality	✓✓✓	✓✓	✓✓	✓	✓	No	Air quality impacts favour residents in the most deprived income quintiles. Those in the most deprived income quintile (Quintile 1), which may be the most vulnerable, experience a higher proportion of air quality benefits than may be expected from an even distribution.
Accessibility	✓*	×*	✓*	✓✓*	✓✓✓*	No*	Improved accessibility to job locations is not distributed evenly across the region. It is likely the negative impacts from increases in congestion outweigh the benefits for suburbs with concentration of low–medium income groups. It is also likely higher income groups benefit most from improved accessibility.
Labour market deepening	✓*	✓*	✓*	✓✓*	✓✓✓*	No*	The benefits will likely improve outputs of job search for the more productive jobs.
Noise	✓*	✓*	✓*	✓*	✓*	Yes*	Noise impacts are appraised as slight benefit for all of the income quintiles and, therefore, although the impact is positive it is distributed evenly.

Source: Principal Economics inspired by DfT (2020a, p. 15)

* Note that the asterisk suggests our evaluation is only qualitative. As we discuss in the following sections, we do not have information on many of the impacts for our current evaluation.

Section 4.3 provides details on distributional impact analysis for each impact, including step 2 (assessment) and step 3 (appraisal) described above.

4.3 Assessment and appraisal of impacts (steps 2 and 3)

This section describes the assessment of distributional impacts identified in Table 4.2 and details the distributional analysis for a specific impact.

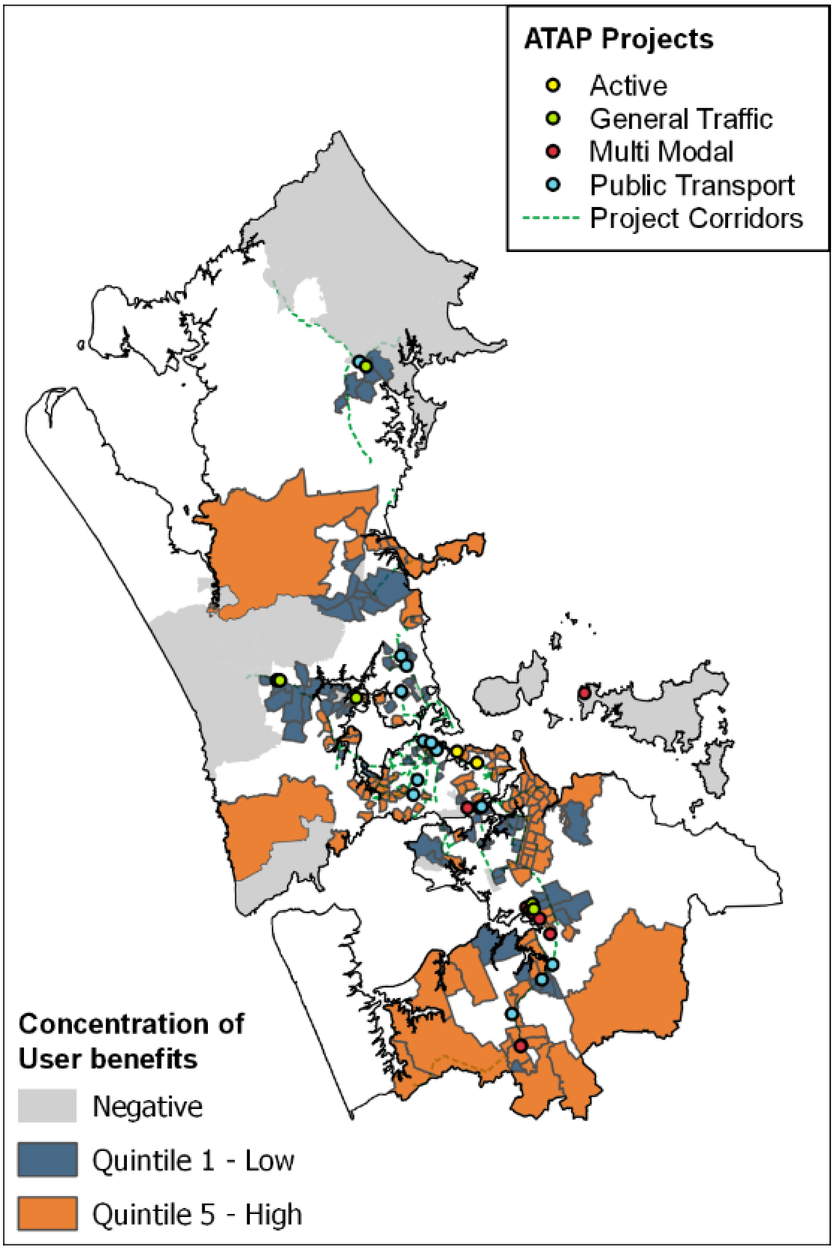
4.3.1 Assessment of the distributional impacts of user benefits

The concentration of user benefit impacts from ATAP is shown in Figure 4.5. The map contains information about the location of the ATAP projects by project type. A comparison between this map and those showing the concentration of socioeconomic features across the Auckland region (Figures 4.1 to 4.4) provides an initial understanding of the likely distribution of user benefits across socioeconomic groups. We provide further details on this next.

4.3.1.1 Step 2 – Assessment

Figure 4.5 shows the identified user benefits for the areas with a net loss and the lower and upper quintiles of the areas with positive net benefits. ATAP investments are associated with mixed (low and high positive) net user benefits across the suburbs located within the middle circle of Auckland. More information on the net benefits to different socioeconomic groups is given below.

Figure 4.5 Distribution of user benefits and the Auckland Transport Alignment Project (ATAP) routes



Source: Principal Economics

Note: We identified user benefits as a combination of private vehicle and public transport time savings benefits, vehicle operational costs and private vehicle reliability benefits. Private vehicle time savings were determined for all origin-destination person car trips using the difference between generalised transport costs (measured in weighted minutes)[60] multiplied by number of car persons for existing users.[61] For each origin-destination, trip purpose and time period, we calculated the consumer surplus for private vehicles using the difference in car persons and generalised costs for scenarios 2031 Do Nothing and 2031 ATAP.[62] Consumer surplus for private vehicle time savings was then converted to hours and multiplied by travel time cost savings and benefit update factors to July 2021.

We applied the same methodology for public transport, using passenger counts and public transport generalised travel costs from MSM outputs.[63, 64]

Vehicle operating costs were determined for each origin-destination, trip purpose, time period and scenario using the change in travel speed, distance, and number of car trips. We determined car speeds (rounded to the nearest 10) by dividing MSM outputs for car distance by car time and applied a composite vehicle operating cost accounting for differences in vehicle operating costs at different speeds.[65] This figure was then multiplied by the distance and number of private vehicle trips, to determine total vehicle operating costs for each transport zone origin-destination car trip, purpose, time period and scenario. This figure was adjusted to July 2021 values and the difference between vehicle operating costs for scenarios 2031 Do Nothing and 2031 ATAP was calculated.

Vehicle reliability is assumed to be 4 percent of vehicle operating costs.

All components of user benefits for the static change in scenarios 2031 Do Nothing and 2031 ATAP were annualised by multiplying the benefits by 245 (number of weekdays in a year) and then backdated to 2021. The roll out of the ATAP was assumed on a pro rata basis of benefit improvements per year over a 10-year period to 2031. The net present value is calculated assuming benefits will remain static after 2031 and at a 4 percent discount rate. Figure 4.2 shows the results of the net present value of the sum of benefits outlined above, distributed by place of residence.[66]

This assessment uses the appraisal outputs from the MSM[67] for the core Do Minimum versus Do Something scenarios. The calculations are based on all trips (that is, for all purposes). Given the range of projects involved in the ATAP across the Auckland footprint, we identified the modelled area to include all Auckland suburbs, as shown in Appendix D. For distributional analysis of area-specific projects, it is important to map the impact area for user benefits and identify any over- or under-representation of the relevant socioeconomic groups (particularly income quintiles) compared with the rest of the region.

User benefits include travel time savings for private vehicle and public transport, vehicle operating costs and vehicle reliability improvement benefits. The time savings for each zone were calculated for each origin-to-destination trip using generalised costs (measured in weighted minutes) from the MSM and applied to the total number of people using private vehicle and public transport. This is undertaken for both the Do Nothing

[60] Generalised transport costs for car trips account for travel time, perceived vehicle operating costs, travel distance, parking costs, tolls or pricing charge, value of time and average car occupancy, varying by purpose and mode.

[61] We use MSM output matrices 11–15 and 26–30 listed in Appendix F for generalised costs, and matrices 31–50 for car persons under each scenario.

[62] We calculated consumer surplus using the rule of half method outlined in the Waka Kotahi monetised benefits and costs manual (MBCM) (Waka Kotahi, 2020, p. 22).

[63] Generalised transport costs for public transport account for total in-vehicle time, access and egress time, headway, number of interchanges, and fares.

[64] We used MSM output matrices 85–94 and 105–114, listed in Appendix F, for generalised costs, and 75–84 and 95–104 for the number of public transport passengers under each scenario.

[65] We include the composite vehicle operating costs we have used in this assessment in Appendix G.

[66] We assumed the places of residence are home-based work (HBW) AM peak (AM) origins and HBW PM peak (PM) destinations and home-based education (HBE) AM origins, and HBE PM and HBE school peak (SP) destinations. This assumption implies that all workers travel to work during the AM period and return in the PM. Similarly, the assumption implies all home to education trips take place in the AM and return in the PM or SP period.

[67] Auckland Regional Transport Model.

and Do Something scenarios, and the rule of half is used to determine the time savings benefit for each zone and mode.[68]

Vehicle operating costs are determined for each origin-to-destination car trip for the Do Nothing and Do Something scenarios before calculating the total difference for each zone. To account for differences in vehicle operating costs for each vehicle class, assuming a road gradient of zero, we derive a composite value of vehicle operating costs for all vehicle classes based on the traffic composition for urban arterial roads at all time periods. To account for changes in road speed, we derive vehicle speed using distance and travel time values for car trips provided by the MSM.

It is not necessary to identify amenities within the impact area for the user benefits distributional impact appraisal. This is because the appraisal focuses on the impact across income groups only, and the impact area is too large to identify local attractors.

4.3.1.2 Step 3 – Appraisal

We identified $4.57 billion (NPV) in user benefits from ATAP projects over 2021–2061. The disaggregated user benefits by income groups are shown in Table 4.8 and compared to the proportion of each income group in the assessment area. Accordingly, the net benefits are positive for all income groups. The difference between the distribution of net benefits and each income group's share of population is small in terms of the magnitude. We have reported the average and standard deviation of the differences at the bottom of the table. We used this information to assign ticks as an indicator of the relative net benefits identified for each income group, as described in Table 4.6.

Table 4.8 Distributional impact appraisal matrix – income distribution

Assessment area – Auckland	Income groups					Total
	Income group 1	Income group 2	Income group 3	Income group 4	Income group 5	
Total households (2031)	104,547	153,905	98,703	140,777	173,145	671,077
Proportion of overall households*	15.58%	22.93%	14.71%	20.98%	25.80%	100%
Overall net benefits† (million $)	984	1,455	944	1,376	1,651	6,409
Share of net benefits‡	15.35%	22.70%	14.73%	21.47%	25.75%	100%
Sum of benefits¶ (million $)	1,032	1,536	998	1,462	1,767	6,795
Distribution of benefits	15.19%	22.61%	14.69%	21.52%	26.00%	100%
Sum of disbenefits§ (million $)	–49	–81	–54	–86	–116	–386
Distribution of disbenefits	12.59%	20.96%	14.09%	22.31%	30.05%	100%
Difference between distributions	–0.23%	–0.23%	0.02%	0.49%	–0.05%	
Mean of the differences	0.00%					
Standard deviation of the means of differences	0.30%					
Assessment	✓	✓✓	✓	✓✓	✓✓✓	✓

Source: Principal Economics inspired by DfT (2020a, p. 23)

* The proportions are calculated by dividing the total household number within each income group by the total number of households.

[68] We have excluded areas that did not previously have any public transport services, given the lack of generalised travel cost data available for the Do Nothing scenario.

† Benefits were calculated at transport zone levels, based on the travel time savings for private vehicle and public transport, vehicle operating costs, and vehicle reliability improvement benefits. The distribution of benefits across income groups is based on the existing household income composition in each zone, approximated based on Census information at statistical area 2 geographic levels.

‡ The shares were calculated by dividing the total benefits accrued to an income group by the total benefits. The benefit shares will be different from the proportion of households within that income group because of the difference in the distribution of benefits across zones.

¶ The benefits were reported for the zones that we identified as experiencing positive impacts, driven by positive time savings.

§ The disbenefits are calculated only for the zones that will be experiencing a negative impact.

4.3.2 Assessment of the distributional impacts of accidents

The approach for the appraisal of accidents uses data from the transport modelling outputs to identify the affected area for the accident assessment.

4.3.2.1 Step 2 – Assessment

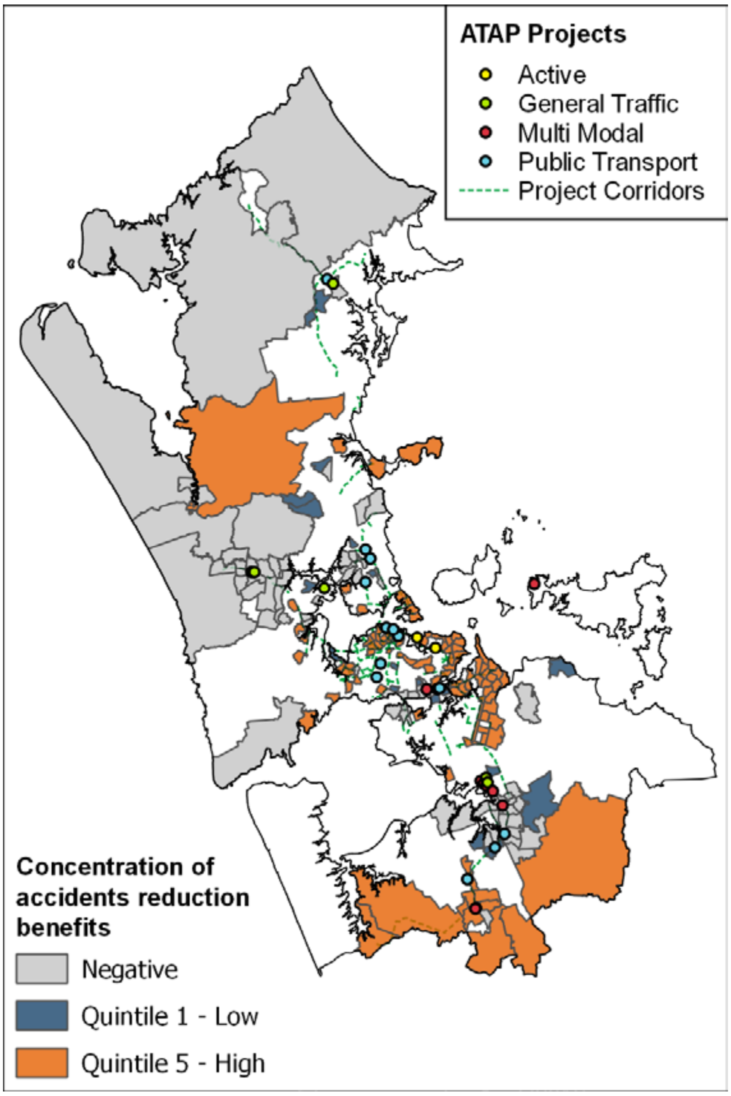
For the assessment, we assumed a 33 percent reduction in deaths and serious injuries (DSIs) leading up to the 2031 ATAP scenario. This follows a linear progression towards Auckland Transport's Transport Safety Strategy goal of having no DSIs on roads by 2050. In further discussions with Auckland Transport teams, they referred to the Programme Business Case of the ATAP and suggested the programme leads to a significantly higher DSI reduction by 67 percent. They also suggested the programme is more focused on volunteer population groups. Our assessment therefore does not fully capture the safety impacts of the ATAP but instead provides an assessment of the safety implications associated with a change in trip making as a result of parts of the 2031 ATAP.

We distribute the accident reduction benefits by place of residence[69] according to the difference in the number of car trips from the 2031 ATAP scenario and 2031 Do Nothing scenario. This assumes the ATAP will lead to a reduction in DSIs for households that reduce their car travel.

The spatial distribution of net benefits of accidents is presented in Figure 4.6. Accordingly, the areas located in the outer circle experience a negative impact. In the following section, we overlap the findings from the spatial assessment with the socioeconomic features of the zones.

[69] We assumed the places of residence are HBW AM origins and HBW PM destinations and HBE AM origins and HBE PM and HBE SP destinations. This assumption implies that all workers travel to work during the AM period and return in the PM. Similarly, the assumption implies all home to education trips take place in the AM and return in the PM or SP period.

Figure 4.6 Distribution of accident reduction benefits and the Auckland Transport Alignment Project (ATAP) routes



Source: Principal Economics

Note: We assumed a 33 percent reduction in the 10 years leading up to the 2031 ATAP scenario. This follows a linear progression towards Auckland Transport's Transport Safety Strategy goal of having no deaths or serious injury on roads by 2050. We distributed the accident reduction benefits by place of residence according to the difference in the number of car trips from the 2031 ATAP scenario and 2031 Do Nothing scenario.[70] The net present value is calculated assuming benefits will remain static after 2031 and at a 4 percent discount rate. Figure 4.6 shows the results of the net present value of accident reduction benefits outlined above, distributed by place of residence.[71]

As described, for our assessment of the case study, we used the outputs of the MSM[72] for the core Do Minimum versus Do Something scenarios. The calculations are based on all trips (that is, for all purposes). Given the range of projects involved in the ATAP across the Auckland footprint, we identified the modelled

[70] We used MSM output matrices 1–10 and 16–25 for the number of car trips.

[71] We assumed the places of residence are HBW AM origins and HBW PM destinations and HBE AM origins, and HBE PM and HBE SP destinations. This assumption implies that all workers travel to work during the AM period and return in the PM. Similarly, the assumption implies all home to education trips take place in the AM and return in the PM or SP period.

[72] Auckland Regional Transport Model.

area including all Auckland suburbs, as shown in Appendix D. For distributional analysis of more area-specific projects and programmes, it is important to map the impact area for impacts on accidents and identify any over- or under-representation of the relevant socioeconomic groups (particularly income quintiles) in the assessment area (in comparison with the rest of the region), as presented in Table 4.9.[73]

Table 4.9 Distribution of income deprivation in the scheme impact area

Income groups	Auckland	Large urban areas	New Zealand
Income group 1 (low tier)	15%	17%	19%
Income group 2 (lower-middle income)	23%	25%	28%
Income group 3 (middle income)	15%	16%	16%
Income group 4 (upper-middle income)	21%	21%	19%
Income group 5 (high income)	26%	22%	18%

Source: Stats NZ Census 2018; Principal Economics calculations

4.3.2.2 Step 3 – Appraisal

Table 4.10 shows the distribution of positive, negative and net impact of accidents. Accordingly, the highest income group benefits most from the improved outcomes.

Table 4.10 Distributional impact appraisal matrix – accidents

Assessment area – Auckland	Income groups					Total
	Income group 1	Income group 2	Income group 3	Income group 4	Income group 5	
Number of households (2031)	104,547	153,905	98,703	140,777	173,145	671,077
Proportion of overall households	15.58%	22.93%	14.71%	20.98%	25.80%	100.00%
Overall net benefits* (million $)	$323	$460	$298	$422	$537	$2,040
Share of net benefits	15.85%	22.55%	14.62%	20.66%	26.31%	100.00%
Sum of benefits (million $)	$340	$488	$317	$452	$579	$2,176
Distribution of benefits	15.61%	22.44%	14.57%	20.77%	26.62%	100.00%
Sum of disbenefits† (million $)	–$16	–$28	–$19	–$30	–$43	–136
Distribution of disbenefits	11.95%	20.74%	13.68%	22.34%	31.30%	100.00%
Difference between distributions	0.28%	–0.38%	–0.08%	–0.32%	0.51%	
Mean of the differences	0.00%					
Standard deviation of the means of differences	0.38%					
Assessment	✓✓	✓	✓✓	✓✓	✓✓✓	✓

Source: Principal Economics

[73] Identification of amenities within the impact area is not required for the user benefits distributional impact appraisal. This is because the appraisal focuses on the impact across income groups only, and the impact area is too large to identify local attractors.

* We distribute the accident reduction benefits by place of residence according to the difference in the number of car trips from the 2031 ATAP scenario and 2031 Do Nothing scenario. This assumes that the ATAP will lead to a reduction in deaths and serious injuries for households that reduce their car travel.

† We distribute the accident disbenefits by place of residence according to the difference in the number of car trips from the 2031 ATAP scenario and 2031 Do Nothing scenario. This assumes that deaths and serious injuries will increase for households that increase their car travel.

For future studies, we suggest further investigation of the method used for distributing the impacts across suburbs. A major investment objective and otherwise a major potential source of inequity is the reduction of DSI crashes. The above analysis was only undertaken at a high level but is taken as a crude estimate of the benefit that would have been derived by applying the MBCM methods. Effectively, these methods trace back to the value of a statistical life (VOSL), which is the average estimated WTP of the adult population for a lower probability of a DSI for an unidentified person within the population. The implications of this methodology for the sensitivity analysis of distributional effects are shown in Table 4.11.

Table 4.11 Implications of findings using value of a statistical life (VOSL) for the analysis of distributional effects

Finding from VOSL	Implication for sensitivity analysis
The willingness to pay (WTP) varies according to the average income of the population and the nature of the risk that the unidentified person is expected to encounter.	Scenario 2a: Include an income growth rate to account for increasing VOSL over time. Scenario 2b: Assume crash risk in Auckland is similar to New Zealand. No change to benefit required.
The WTP is higher if the unidentified person was to be identified as a child, but it is unclear what this premium for avoiding death and serious injury (DSI) for children is. Further complicating the application of this finding, there appears to be some trade-off within the household such that the WTP to avoid death of people within a household with dependant children does not differ from households without dependant children.*	Scenario 2a: No adjustment required. Scenario 2b: No reweighting for children required because Auckland %children similar to New Zealand. Difference is higher %households with children but no conclusive evidence of WTP premium. So no adjustment required.
The benefits of reduced DSI are long-lasting and likely to entail intergenerational influences.	Scenario 4: Include benefit as long term.

Source: Principal Economics

* The upcoming Waka Kotahi (in press) report will provide further information on this.

4.3.3 Assessment of the distributional impacts of local air quality

The reduced emissions and noise benefits – both externalities – will also be used as proxies for the MBCM measure of benefit. The MBCM has a thorough method for estimating the greenhouse gas emissions benefit, and no further adjustment was considered for our analysis. Also, given the effects of greenhouse gas emissions are largely global, little direct local distribution effects of this benefit occur and so no further sensitivity analysis was required for the equity purposes discussed in section 4.4.[74]

Given the top-down estimation process, the localised emissions and noise benefits were relatively small. However, for completeness, it is appropriate they are adjusted in the same manner as crash safety, given a similar link back to VOSL.

[74] However, large distributional concerns exist about climate change effects, which would show under transport users' benefits and the residual value of infrastructure applied in a CBA. It would be appropriate to analyse these uncertain effects under the scenario framework suggested here, but that is beyond the scope of this case study.

Similar to the other impacts, it is recommended a concentration map is provided of the local air quality impacts. We identified an NPV of $40 million for local air quality from ATAP projects for 2021–2061. However, in our analysis of the ATAP, we did not have the required information on routes for journeys for disaggregating the identified benefits across suburbs.

4.3.3.1 Step 2 – Assessment

As described, for our assessment of the case study, we used the outputs of the MSM[75] for the core Do Minimum versus Do Something scenarios. The calculations are based on all trips (that is, for all purposes). The modelled area includes all Auckland suburbs, as shown in Appendix D. For distributional analysis of area-specific projects and programmes, it is important to map the impact area for local air quality benefits and identify any over- or under-representation of the relevant socioeconomic groups (particularly income quintiles) in the assessment area (in comparison with the rest of the region). However, as explained in the next section, we were not able to further investigate impacts on socioeconomic groups in our distributional impact analysis of the case study.

4.3.3.2 Step 3 – Appraisal

Table 4.12 shows the disaggregated air quality benefits by income groups, including comparisons of benefits, disbenefits and net benefits across different income groups (this does not account for any features of the case study). Depending on the availability of information, the outputs could be reported at the transport zone levels or a granular geographic level. As usual, the findings are presented in the assessment row of the Table 4.12, providing information about the distribution of net benefits across income groups.

Table 4.12 Distributional impact appraisal matrix – air quality

Impact area	Income groups					Total
	Income group 1	Income group 2	Income group 3	Income group 4	Income group 5	
Number of winners	$\#G_1$	$\#G_2$	$\#G_3$	$\#G_4$	$\#G_5$	$\#G_t$
Percentage winners and losers	$\%G_1$	$\%G_2$	$\%G_3$	$\%G_4$	$\%G_5$	100%
Overall net benefits	$\#G_1$	$\#G_2$	$\#G_3$	$\#G_4$	$\#G_5$	$\#G_t$
Share of net benefits	$\%G_1$	$\%G_2$	$\%G_3$	$\%G_4$	$\%G_5$	100%
Sum of benefits	$\#G_1$	$\#G_2$	$\#G_3$	$\#G_4$	$\#G_5$	$\#G_t$
Distribution of benefits	$\%G_1$	$\%G_2$	$\%G_3$	$\%G_4$	$\%G_5$	100%
Sum of disbenefits	$\#G_1$	$\#G_2$	$\#G_3$	$\#G_4$	$\#G_5$	$\#G_t$
Distribution of disbenefits	$\%G_1$	$\%G_2$	$\%G_3$	$\%G_4$	$\%G_5$	100%
Assessment	✓	✓	✓	✓	✓	✓

Source: Principal Economics inspired by DfT (2020a, p. 27)

Note: $\#_1$ to $\#_5$ present the numbers of people within each income group; $\#G_t$ is the total number of people; $\%G_1$ to $\%G_5$ present the percentage of benefits and losses to each income group.

[75] Auckland Regional Transport Model.

4.3.4 Assessment of the distributional impacts of security

While our qualitative assessment in Table 4.2 identified security as an important impact of the ATAP for further distributional assessment, we do not have enough information for this analysis. We discuss the information required for this analysis in section 5.3.

4.3.5 Assessment of the distributional impacts of severance

A potential disbenefit often raised with transport projects that can affect various groups is the severance a project may cause, because of transport infrastructure becoming a barrier between where people live and where they go. In Table 4.2, we suggest further analysis of distributional impacts of severance outcomes of the ATAP is required.

Anciaes et al. (2016) discuss the measurement of severance. To date, it appears that measurement has largely been of extra waiting and walking time for pedestrians. It is also possible to estimate a WTP[76] to remove severance, although challenges occur with disentangling the possible causes of any grievance and double-counting is also a risk. Nonetheless, if severance was a major issue in a project, these are methods to: (a) identify the people affected and show distributional effects (within scenario 1) and (b) incorporate monetary values for severance in a CBA (within scenario 2).

We do not have enough information about the measurement of severance for this analysis. This is highlighted in the limitations of our study in section 5.3.

4.3.6 Assessment of the distributional impacts of accessibility

In our qualitative assessment in Table 4.2, we identified accessibility as an important impact of the ATAP for further distributional assessment.

4.3.6.1 Step 2 – Assessment

As noted, for our assessment of the case study, we used the outputs of the MSM[77] for the core Do Minimum versus Do Something (ATAP) scenarios. The calculations are based on all trips (that is, for all purposes). Given the range of projects involved in the ATAP across the Auckland footprint, we identified the modelled area as including all Auckland suburbs, as shown in Appendix D. For distributional analysis of area-specific projects and programmes, it is important to map the impact area for accessibility impacts. It is also important to identify any over- or under-representation of the relevant socioeconomic groups (particularly income quintiles) in the assessment area (in comparison with the rest of the region), as presented in Table 4.9.

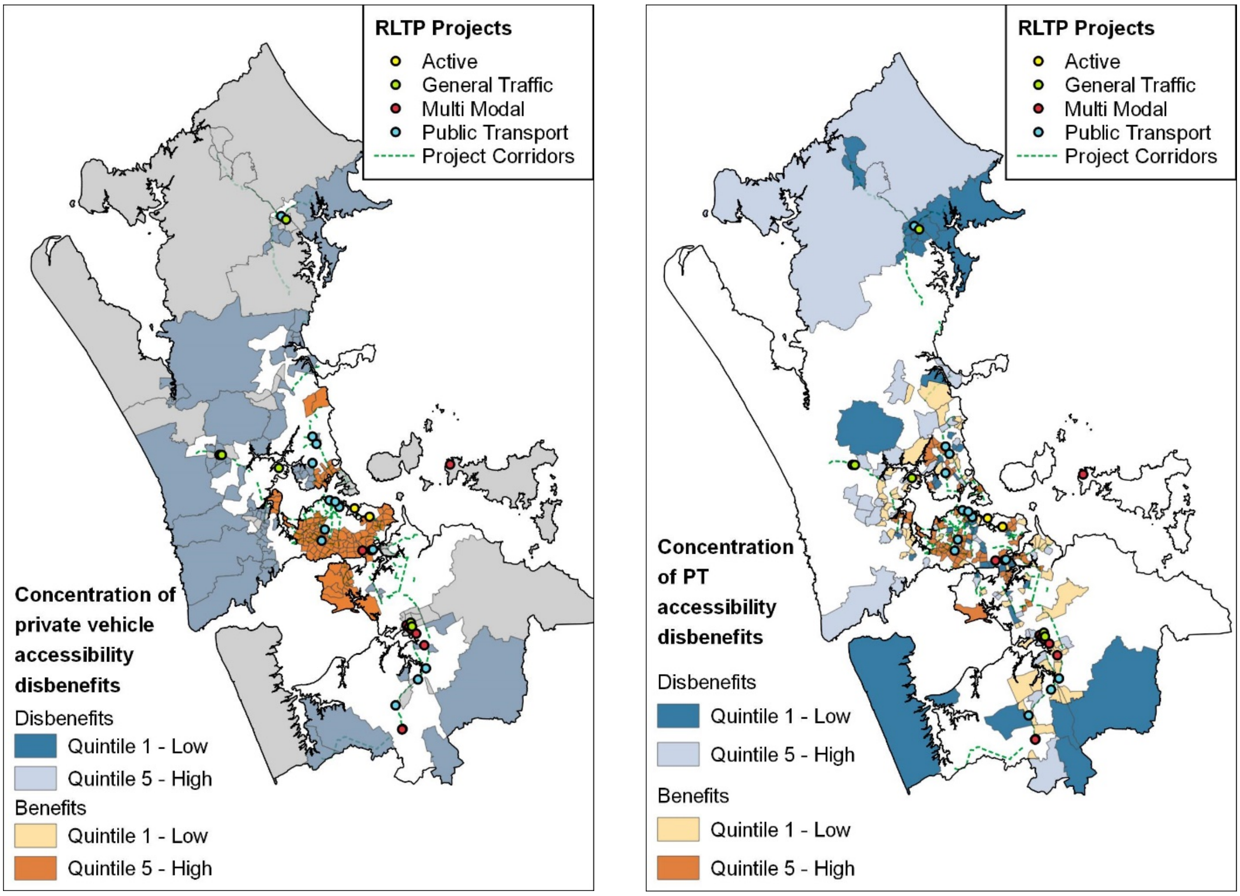
Accessibility is based on the number of jobs accessible to zones during the AM peak hours for HBW travellers. For public transport, we have determined accessibility as the number of jobs accessible to zones within a 45-minute journey time; private vehicle accessibility is based on the number of jobs accessible to zones within a 30-minute travel time. We use the number of jobs projected to 2031 in the Auckland Council Land Use Scenario i11.6 for each transport zone.

The spatial distribution of net benefits of accessibility is presented in Figure 4.7, which shows the changes in accessibility of private vehicles on the left-hand side and changes in accessibility of public transport users on the right-hand side. In section 4.3.6.2, we present the outcome of overlaying the spatial distribution of accessibility changes with the spatial distribution of socioeconomic groups.

[76] Or a willingness to accept.

[77] Auckland Regional Transport Model.

Figure 4.7 Distribution of private vehicle and public transport accessibility benefits and the Auckland Transport Alignment Project routes



Source: Principal Economics

Note: PT = public transport; RLTP = Regional Land Transport Plan. For this assessment, we define accessibility as the total number of jobs that can be reached by private vehicle in 30 minutes and public transport in 45 minutes during the AM peak period. We use employment projections provided by Auckland Transport for Auckland Council's Land Use Scenario i11.6 and MSM outputs for car time and public transport journey times for HBW AM peak periods.[78]

4.3.6.2 Step 3 – Appraisal

To allocate benefits across socioeconomic groups, we assume the improved accessibility (dis)benefits calculated at the zone level will be allocated equally to all socioeconomic groups in that zone. For example, if 1,000 more jobs are accessible, all the low household income groups in that zone have access to 1,000 more jobs. Then, across the region, we find a distribution of the increase (decrease) in access to jobs for each income group. We then identify the number of households and the median increase (decrease) in access to jobs based on that distribution.

Table 4.13 and Table 4.14 show the findings from our step 3 appraisal of distributional impacts of changes in accessibility (to jobs) of private vehicle and public transport. Our analysis is limited to the AM peak period. For each income group, we show the total number of households and total number of jobs that resulted from the positive, negative and net impacts of changes in accessibility. We also present the total number of households in each income group for the areas without any changes in jobs accessible by public transport.

[78] We used MSM matrices 51, 57, 63 and 95 for changes in private vehicle and public transport travel times between the 2031 Do Nothing and 2031 ATAP scenarios.

The figures in the rows of changes in numbers (of the jobs accessible and households affected) show the difference in the median for each income group from the median of the region. For example, the net benefits rows in Table 4.14 present the median of the change in number of jobs accessible by public transport for each income group. Accordingly, the median increases in the number of jobs accessible for income groups 1 and 4 are 9,368 and 8,548, respectively. The median for the whole impact area is 9,085. The difference from the median change in job accessibility is shown in the last row of the net benefits section. Accordingly, income group 5 experiences around 21 percent higher improved accessibility compared with the median of the impact area. This is higher than the benefits accrued to other income groups.[79]

Table 4.13 Distributional accessibility impacts – number of jobs accessible by car in 30 minutes during the AM peak period

Assessment area – Auckland	Income groups					Total
	Income group 1	Income group 2	Income group 3	Income group 4	Income group 5	
Number of households* (2031)	104,547	153,905	98,703	140,777	173,145	671,077
Proportion of overall households	15.58%	22.93%	14.71%	20.98%	25.80%	100.00%
Net benefits	**Income groups**					**Total/median**
Number of households* (2031)	103,079	151,798	97,235	138,834	170,823	661,769
Percentage of households	15.58%	22.94%	14.69%	20.98%	25.81%	100.00%
Change in number of jobs accessible (median)	18,078	17,196	17,525	17,525	21,845	17,999
% Difference from the median change in jobs accessibility†	0.44%	–4.46%	–2.63%	–2.63%	21.37%	0.00%
Benefits	**Income groups**					**Total/median**
Number of households* (2031)	95,263	139,914	90,153	129,023	158,914	613,267
Percentage of households	15.53%	22.81%	14.70%	21.04%	25.91%	100.00%
Change in number of jobs accessible (median)	22,642	18,692	20,648	20,229	24,989	22,044
% Difference from the median change in jobs accessibility	2.71%	–15.20%	–6.33%	–8.23%	13.36%	0.00%
Disbenefits	**Income groups**					**Total/median**
Number of households* (2031)	6,095	9,308	5,747	8,082	9,820	39,052
Percentage of households	15.61%	23.83%	14.72%	20.70%	25.15%	100.00%
Change in number of jobs accessible (median)	–5,074	–3,089	–2,340	–2,340	–5,074	–3,089
Difference between distributions	0.44%	–4.46%	–2.63%	–2.63%	21.37%	
Mean of the differences	2.42%					
Standard deviation of the means of differences	10.47%					
Assessment	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓

Source: Principal Economics

[79] Our criteria for assigning ticks (ie evaluating the importance of distributional effects) is different from the approach described in Table 4.6. This is because we have estimated benefits in terms of difference in the median of each income group from the median of the region. Hence, we used the distribution of that difference and its average and standard deviation for assigning the ticks.

Note: The last column (Total) in the tables shows the total for the percentage rows, and the difference from median for the other rows.

* The total number of households for the net benefits includes the total number of households identified in our assessment. This is the sum of the number of households that experience benefits, disbenefits and no changes. The total number of households identified in our analysis (661,769) is slightly different from the first row of the table, which shows the total number of households reported in Auckland Council's population forecasts. This is because we could not identify the existing household income groups within some transport zones using the Census data.

† The percentage difference for the median change in jobs accessible is calculated based on the percentage difference between the median change in the number of jobs accessible relative to the regional median. For example, the difference for income group 2 is equal to 0 percent, calculated as (17,196 – 17,999)/17,999.

Table 4.14 Distributional accessibility impacts – number of jobs accessible by public transport in 45 minutes during the AM peak period

Assessment area – Auckland	Income groups					Total
	Income group 1	Income group 2	Income group 3	Income group 4	Income group 5	
Number of households* (2031)	104,547	153,905	98,703	140,777	173,145	671,077
Proportion of overall households	15.58%	22.93%	14.71%	20.98%	25.80%	100.00%
Net benefits	**Income groups**					**Total/median**
Number of households* (2031)	98,672	144,389	93,331	133,863	165,611	635,866
Percentage of households	15.52%	22.71%	14.68%	21.05%	26.04%	100.00%
Change in number of jobs accessible (median)	9,368	8,888	8,806	8,548	9,313	9,085
% Difference from the median change in jobs accessibility†	3.12%	–2.16%	–3.07%	–5.92%	2.51%	0.00%
Benefits	**Income groups**					**Total /median**
Number of households* (2031)	79,374	115,120	74,131	105,757	131,042	505,424
Percentage of households	15.70%	22.78%	14.67%	20.92%	25.93%	100.00%
Change in number of jobs accessible (median)	13,844	12,891	12,961	12,586	14,812	13,416
% Difference from the median change in jobs accessibility	3.19%	–3.92%	–3.39%	–6.18%	10.41%	0.00%
Disbenefits	**Income groups**					**Total/median**
Number of households* (2031)	14,723	21,799	14,520	20,951	25,505	97,498
Percentage of households	15.10%	22.36%	14.89%	21.49%	26.16%	100.00%
Change in number of jobs accessible (median)	–4,309	–4,513	–4,513	–4,513	–5,113	–4,563
% Difference from the median change in jobs accessibility	–5.56%	–1.09%	–1.09%	–1.09%	12.05%	0.00%
No change	**Income groups**					**Total /median**
Number of households* (2031)	4,575	7,470	4,680	7,155	9,064	32,944
Percentage of households	13.89%	22.67%	14.21%	21.72%	27.51%	100.00%
Difference between distributions	0.44%	–4.46%	–2.63%	–2.63%	21.37%	
Mean of the differences	2.42%					
Standard deviation of the means of differences	10.47%					
Assessment	✓✓✓	✓	✓	✓	✓	✓

Source: Principal Economics

Note: The last column (Total) in the table shows the total for the percentage rows, and the difference from median for the other rows.

* The total number of households for the net benefits includes the total number of households identified in our assessment. This is the sum of the number of households that experience benefits, disbenefits and no changes. The total number of households identified in our analysis (635,866) is slightly different from the first row of the table, which shows the total number of households reported in Auckland Council's population forecasts. This is because we could not identify the existing household income groups within some transport zones using the Census data.

† The percentage difference for the median change in jobs accessible is calculated based on the percentage difference between the median change in the number of jobs accessible relative to the regional median. For example, the difference for income group 1 is equal to 3 percent, calculated as (9,368 – 9,085)/9,085.

4.3.7 Assessment of the distributional impacts of labour market deepening

Searle and Legacy (2019) raised the potential for labour market deepening as a possible missing benefit in Australia. People who are likely to increase their wage income following a reduction in generalised travel costs are those who face travel threshold effects, such as disabled people and people without a car (now able to gain access to more jobs), households with dependant children (tight timetables) and generally people on low wages (transport costs a significant proportion of wages).

The MBCM provides procedures to estimate the welfare effects of extra labour hours (section 3.11) and wage rates (sections 3.10–3.11) for a major transport project (Waka Kotahi, 2021b). These have been shown to be up to 50–100 percent of transport generalised cost savings for a major Auckland public transport project (Auckland Manukau Eastern Transport Initiative Stage 2A).

It was not possible to apply these methods in this case study. However, if the analyses were undertaken, then the MBCM methods are sufficiently defined and localised to not require further adjustment in scenarios 2a and 2b. The distribution of these wider economic benefits will be a function of both generalised travel cost savings and employment density.[80] These benefits could be calculated for the origin zones of the home–work journey and the same disaggregation method used above to disaggregate by income groups, or any other grouping applied above. Disaggregation of wider economic benefits by income groups would then provide the data to apply the welfare weights in scenario 3. As noted, this was not done in this case study.

4.3.8 Assessment of the distributional impacts of social cohesion

A potential disbenefit often raised regarding transport projects that can affect a range of groups is the social cohesion impacts of a project, with a special case being gentrification.

Social cohesion is a multi-dimensional topic that appears to reduce core elements, such as social relations, identification and orientation towards the common good (Schiefer & van der Noll, 2017). Another attempt to reduce the dimensions of social cohesion is that of Bottoni (2018), who found seven main explanatory factors of inter-country social cohesion. Extending Bottoni's analysis, it is likely a transport project can affect social cohesion through both the project management side, via factors such as participation, openness, institutional trust and legitimacy of institutions, and the project outcome side, via factors such as participation,[81] interpersonal trust, density of social relations and social support.

Two challenges are involved in applying measures of social cohesion to transport projects. The first is that no widely used method exists for measuring social cohesion. The second is the conceptual difficulty of to

[80] For further details, see section 2.1.2.4 and section 2.3.6

[81] There is participation in the change process and also the project affecting (positively or negatively) a person's participation in the economy and community; the former is a matter of engagement and the latter is related to accessibility.

what extent any disbenefit (or benefit) would be attributed to the transport project or, instead, to the local body planning changes that would likely coincide with the transport project.

For measurement, it would be possible to apply WTP or willingness to accept surveys and/or life satisfaction surveys. Attribution likely requires a decremental measurement approach.[82]

Given this was not an issue raised in this case study, the methods and difficulties are simply noted rather than explored further.[83]

4.3.9 Assessment of the distributional impacts of noise

While our qualitative assessment in Table 4.2 identified noise as an important impact of the ATAP for further distributional assessment, we do not have enough information for this analysis. We discuss the information required for this analysis in section 5.3.

4.3.10 Assessment of the distributional impacts of affordability

Changes in affordability because of transport intervention have significant implications for the distributional impact analysis. The changes in affordability have significant effects on travel costs for young and old people, and low-income households, particularly when travelling to employment or education. People with disabilities may also suffer significant disbenefits when faced with higher costs, due to limited transport choices (Torshizian, 2019).

For the methodology, we calculated the sum of vehicle operating costs and public transport fares paid in each zone and divided this by the number of users, to determine the amount spent by users of both private vehicles and public transport services. To find the change in affordability for each zone, we found the difference in travel spending per person under the Do Nothing and ATAP scenarios. The per-person values were converted to households using population per household ratios and annualised based on 245 weekdays per year, to determine the change in annual travel affordability for households.

4.3.10.1 Step 2 – Assessment

As noted, for our assessment of the case study, we used the outputs of the MSM[84] for the core Do Minimum versus Do Something scenarios. The calculations were based on all trips (that is, for all purposes). Given the range of projects involved in the ATAP across the Auckland footprint, we identified the modelled area including all Auckland suburbs, as shown in Appendix D.

Figure 4.8 shows the spatial distribution of net benefits of affordability across zones. For distributional analysis of area-specific projects and programmes, we mapped the spatial distribution of affordability impacts and identified any over- or under-representation of the relevant socioeconomic groups (particularly income quintiles) in the assessment area (in comparison with the rest of the region). This is discussed in the next step – appraisal.

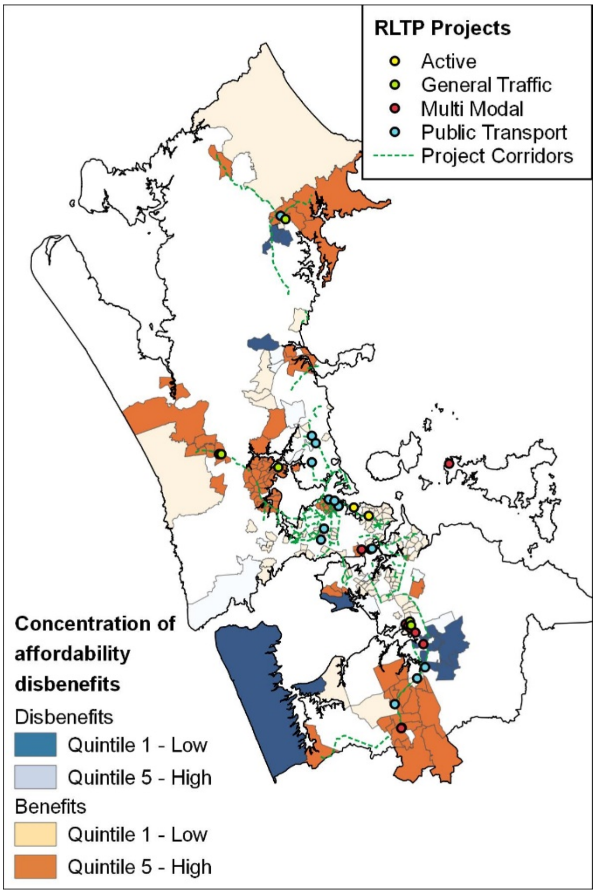
---

[82] What is the outcome of policy changes and transport changes if one were not to occur?

[83] The current transport appraisal guidelines do not provide information about assessment of social cohesions. Inspired by Torshizian (2017), we suggest further investigation of the change in 'own group' attraction factors, such as ethnicity and income groups. Therefore, a change from the average regional levels suggests potential social cohesion outcomes.

[84] This is Auckland's Regional Transport Model.

Figure 4.8 Distribution of affordability benefits and the Auckland Transport Alignment Project routes



Source: Principal Economics

Note: RLTP = Regional Land Transport Plan. Affordability is determined by calculating the sum of total vehicle operating costs and public transport fares paid per transport zone and dividing this by the number of private vehicle and public transport users within the zone. This provides an estimate of the price paid per person for transport. We annualised the result by multiplying MSM outputs by 245 (number of weekdays in a year).

4.3.10.2 Step 3 – Appraisal

To allocate benefits across socioeconomic groups, we assumed the improved affordability (dis)benefits calculated at the zone level would be allocated equally to all socioeconomic groups in that zone. For example, if 1,000 more jobs are accessible, everyone in the low household income group in that zone has access to 1,000 more jobs. Then, across the region, we found a distribution of the increase (decrease) in access to jobs for each income group. We identified the number of households and the median increase (decrease) in access to jobs based on that distribution.

Table 4.15 shows the findings from step 3 (appraisal of changes in affordability). For each income group, we show the total number of households affected and the average changes in affordability disaggregated for the positive, negative and net impacts of changes in affordability.

The results of our assessment suggest a relatively equal distribution of benefits across different income groups. The change in affordability rows show the savings to each income group. The 'difference from the median' rows provide information on the savings to an income group compared with the average savings (across all income groups). Accordingly, slightly higher benefits occur for income group 1 and some disbenefits for income group 4 (compared with income groups 2 and 5). However, (absolute) benefits are higher for the high-income group compared with the rest.

Our findings from the affordability analysis suggest minor differences across income groups (in terms of the magnitude of difference). This is partly because changes in affordability identified from the changes in fares and vehicle operating costs are small, based on the inputs of our analysis provided by the MSM. Also, an important limitation of our affordability analysis is the lack of active mode data. Given the importance of an active mode for affordable commute, we suggest the findings of our analysis of affordability will be different once we account for active mode. This is particularly important because the affordability gains provided by accessibility improvements to non-auto modes allow households to reduce their car ownership.[85]

Table 4.15 Distributional affordability impacts – change in household spending on vehicle operating costs and public transport fares

Assessment area – Auckland	Income groups					Total
	Income group 1	Income group 2	Income group 3	Income group 4	Income group 5	
Number of households	104,547	153,905	98,703	140,777	173,145	671,077
Proportion of overall households	15.58%	22.93%	14.71%	20.98%	25.80%	100.00%
Net benefits	**Income groups**					**Total**
Number of households (2031)	101,959	150,297	96,559	138,030	169,963	656,808
Percentage of households	15.52%	22.88%	14.70%	21.02%	25.88%	100.00%
Change in affordability ($ per annum per person)	22.52	22.22	21.98	21.92	22.22	22.22
Difference from the median change in affordability	1.38%	0.00%	–1.07%	–1.34%	0.00%	0.00%
Benefits	**Income groups**					**Total**
Number of households (2031)	90,701	132,065	84,783	119,924	147,413	574,886
Percentage of households	15.78%	22.97%	14.75%	20.86%	25.64%	100.00%
Change in affordability ($ per annum per person)	24.46	24.62	24.37	24.37	25.24	24.62
Difference from the median change in affordability	–0.64%	0.00%	–1.03%	–1.03%	2.51%	0.00%
Disbenefits	**Income groups**					**Total**
Number of households (2031)	11,258	18,232	11,776	18,106	22,550	81,922
Percentage of households	13.74%	22.26%	14.37%	22.10%	27.53%	100.00%
Change in affordability ($ per annum per person)	–21.34	–21.34	–21.34	–21.51	–21.34	–21.34
Difference from the median change in affordability	0.00%	0.00%	0.00%	0.78%	0.00%	0.00%
Difference between distributions	0.33%	0.18%	0.09%	–0.29%	–0.31%	
Mean of the differences	0.00%					
Standard deviation of the means of differences	0.29%					
Assessment	✓✓✓	✓✓	✓✓	✓	✓	✓

Source: Principal Economics

[85] Future analyses of affordability should also consider accounting for ownership costs.

4.4 Sensitivity analysis (step 4)

As described in section 4.2.1, the starting point for method B is the MBCM benefit analysis, including measures of benefit distribution, as partially provided for in the ATAP 2021–2031 investment plan. We now consider whether benefits of an equity nature could better be estimated by methods not listed in the MBCM.[86]

A list of potential equity issues is given in Table 4.3, and Table 4.5 shows that the study area (Auckland, in this case) has higher than national proportions of higher-income households, elderly, Pacifica and households with dependant children, plus relatively fewer Māori. Finally, the Regional Land Transport Plan identified key objectives for the planned major investments, as shown in Table 4.1. Together, these tables and reports inform where issues of equity deserve closer analysis, as developed below.

4.4.1 Income effects

The distribution of benefits by income groups was provided in section 4.3. These figures show that benefits were largely proportionate to the size of the population within each income group. This suggests that applying welfare weights to income groups in this case study was unlikely to materially change the final benefit measure. Nonetheless, for completeness, welfare weights were applied to those benefits that affected the local population and presented as scenario 3.

4.4.2 Intergenerational effects

The matter of intergenerational equity is becoming of increasing interest due to the potential damage from climate change effects. Intergenerational inequities are likely to occur when effects are long lasting. The approach here, which is consistent with the MBCM, is to account for long-lasting effects by applying a longer period of benefit assessment and a lower discount rate within scenario 4.

This matter fits within the general CBA issue of the residual value of a project. It is a matter of efficiency whether a project option with a low residual value but high immediate value is chosen over another project with high residual value. The MBCM allows for assessment of this efficiency, either by using a residual value at 40 years or a 60-year benefit period. This is not the topic of this research study.

The equity issue is about (a) the magnitude of disbenefits left to the current young and future generations and (b) the current preference for consumption by the current generation versus consumption by future generations. Examples of the first effect include local environment and health damage so are suited for inclusion in scenario 4, as discussed above. Generally, if more emphasis is to be placed on the legacy value of a project, then use of a longer benefit period (a means of accounting for a legacy value[87]) and a lower discount rate (a means of acknowledging intergenerational preference) is appropriate. However, it is acknowledged that uncertainties about these longer-term benefits can be substantial, so it is appropriate to consider these measures using sensitivity analysis.

In this case study, all benefits were adjusted in scenario 4 on the assumption that longer-term value was created by the projects. It is possible to test the sensitivity of this assumption for each benefit stream, although this was not done here.

[86] This is not a criticism of MBCM methods but an acknowledgement that context and uncertainty may require more emphasis on benefits that are not otherwise estimated.

[87] Increasing the benefit period for a project from 40 years to 60 years would add 50 percent of a year-40 residual value if using a 3 percent per year real discount rate and assuming relatively stable benefit flows in years 41 to 60.

4.4.3 Other potential equity-related benefits and disbenefits

A list of other potential matters of relevance is provided in Appendix E. In many cases, insufficient data were available (in the time available) to assess the importance of the issue and to consider a method to measure the quantum of the benefit or disbenefit. Thus, no further adjustments were made to the scenarios.

4.4.4 Benefits for each scenario

The results of the five scenarios are given in Table 4.16. Scenario 2a and scenario 2b results are shown combined, given no adjustments were undertaken for scenario 2b. On reflection, combining scenarios 2a and 2b is likely to be a more practical general solution. We could not provide further sensitivity analysis for the outputs of our affordability and accessibility analysis because our analysis did not provide a summary dollar figure.

Table 4.16 Benefits of Auckland Transport Alignment Project by scenario ($ million)

Impact	Scenario 1 MBCM	Scenario 2a and 2b plus WTP not in MBCM	Scenario 3 welfare weighted	Scenario 4 lengthened duration
User benefits	3,644	3,644	3,822	5,422
Local air quality	7	8	–	10
Accidents	2,040	2,338	2,465	3,036
Total (PV)	**5,861**	**6,159**	**6,532**	**8,637**

Source: Principal Economics

Note: MBCM = Waka Kotahi monetised benefits and costs manual; PV = present value; WTP = willingness to pay.

The sensitivity analysis in this case did not lead to materially different benefit estimates between scenarios 1, 2, 3 and 4.[88]

The improvement in local air quality and noise, both due to less private vehicle use for commuting to and from work and education institutes, was estimated to have a low monetary value, and so any further adjustment to these figures has only a relatively small effect on total benefits. However, the benefit estimates for these benefit streams were higher when the fuller effects were accounted for.

The benefit of accident reductions is more substantial and the adjustments are accordingly higher.

The welfare weighted benefit estimates in scenario 3 were only slightly higher (around 11 percent) than the unweighted benefit estimates in scenario 2. This reflects the relatively even distribution of benefits by income groups in this case, at least at the zone average level. Recall that this analysis was not able to consider the effect on individuals within a zone.

The benefit estimates provided, by giving more weighting to long-term effects, are significantly higher (47 percent) than the MBCM standard estimate.

4.5 Case study findings and further discussion

Table 4.17 summarises the findings from the assessment of distributional effects across household income groups.

[88] Keeping in mind these are only partial estimates of the benefits of the ATAP 2021–2031 investments.

Table 4.17 Summary of the distributional analysis across household income groups

Social group	Household income groups				
	1) $1–$30,000	2) $30,000–$70,000	3) $70,000–$100,000	4) $100,000–150,000	5) $150,000 or more
User benefits	✓✓	✓✓	✓✓	✓✓✓	✓✓
Air quality	–	–	–	–	–
Accidents	✓✓	✓	✓✓	✓✓	✓✓✓
Security	–	–	–	–	–
Severance	–	–	–	–	–
Accessibility	✓✓	✓✓	✓✓	✓✓	✓✓✓
Labour market deepening	–	–	–	–	–
Social cohesion	–	–	–	–	–
Affordability	✓✓✓	✓✓	✓✓	✓	✓

Source: Principal Economics

The process of analysing the distributional mix of benefits, and consideration of where these benefits and disbenefits might not be captured within a standard MBCM CBA, drew attention to potential inequities.

The case study confirmed more could be done within the CBA process to put potential inequities into perspective. By undertaking this analysis within a scenario framework, decision-makers can choose to accept the implicit weighting given to benefit distribution within the CBA or apply different weightings outside the CBA. For example, more effort was applied in this case study to measure the WTP of the current and future population for reduced serious accident risks. It was found (subject to large estimation error, given the high-level nature of this analysis) that a high weight has already been applied within the CBA (up to $3 billion of benefits relative to $3.6 billion to $5.4 billion transport user benefits, depending on how much emphasis is put on project legacy effects). Decision-makers may wish to accept this weighting or choose another.

The (crude) estimation of the income-weighted welfare benefit in scenario 4 suggests the ATAP projects were distributed relatively evenly over income groups. This is useful information to a decision-maker and could be used as an input to an MCA.

Based on our discussions around sensitivity analysis, we provide the following guidance on the usefulness of the scenarios:

- For long-lasting environment and health effects, use scenario 4.
- If legacy is important, use scenario 4; if not, use scenarios 1 to 3.
- If major uncertainty exists (either about occurrence or estimation method), put more reliance on scenario 1.
- If the findings from scenario 3 are similar to scenarios 1 and 2, downplay inequity concerns.
- If scenario 3 provides much higher impacts than scenarios 1 and 2, then further investigation is needed into what can be done to reduce inequity impacts (or accept knowing they exist).
- If major benefits are not being recognised within MBCM procedures, put more emphasis on scenario 2 (this could also apply to other issues, such as project interdependencies and major uncertainties).

5 Conclusion

This chapter summarises the research findings and offers recommendations for future research. Its structure follows the objectives of the research project.

5.1 Concluding comments

This study identifies and assesses different types of distributional and equity impacts that could arise as a result of transport interventions and initiatives. To provide a useful method for quantifying distributional effects, we consider various criteria, including consistency with the Waka Kotahi MBCM. We applied our identified method to a case study (ATAP 2021–2031) and set out guidance on implementing the preferred method and interpretating the findings from distributional analysis.

Distributional analysis provides further information for policy-makers. The CBA can be used to both (a) measure the distribution of effects and (b) better quantify benefits and disbenefits of relevance to equity.

We investigated the role of the CBA in addressing equity effects using the available literature on transport CBA and measurement of equity. Our literature review suggests that, while CBA is not concerned with distributional effects, equity effects play a significant role in transport decision-making. This is because the benefits of transport investments are not necessarily distributed equally, due to differences in affordability and accessibility to the provided goods and services, which leads to (often) unintended social outcomes.

Transport equity discussions focus on social justice. For the measurement of equity, it is necessary to identify the equity type and segment of society affected by an intervention and identify and measure the range of outcomes. Amongst the theories of justice, further emphasis has recently been given to Sen's capability approach, which includes individuals' ability to move freely from place to place to improve their 'capabilities' and achieve their 'functionings'. For the population groups, various segments have been considered in the literature. The most common feature considered for the definition of population groups was income levels. For identifying impacts, accessibility impacts of transport initiative investments have been widely used in the literature.

We identified various mitigating forms or types of mitigation policies and measures to address adverse distributional impacts. Our literature review suggests the most common approach amongst the studies that consider the CBA framework in their appraisals is to address the shortcomings of the CBA using MCA. The use of MCA to consider equity effects is consistent with Waka Kotahi MCA guidelines. Consistent with the available guidelines, we suggest the issues of distributive justice should be considered alongside the results of CBA, and different theories of distributive justice may be considered relevant. Accordingly, we suggest the analysis of equity impacts should be provided for policymakers to decide.

An MBCM-consistent distributional analysis needs to provide equity estimates across various impacts and by considering different scenarios. The output measures from distributional analysis can also be used in a subsequent MCA, either instead of or to inform qualitative measures.

We examined the practical implications of using alternative distributional weights within a CBA more closely by using a hypothetical example. We then developed a set of weighting options likely to be viable and criteria against which to judge each method. Based on our extensive literature review, we identified four methods for consideration of equity within a CBA. The following sections provide further details on these methods.

5.1.1 Method A: Status quo

The current Waka Kotahi MBCM method is to evaluate and report the distribution of benefits and costs, particularly where they relate to the needs of transport disadvantaged populations. In this study, we identified a range of impacts to be considered for the distributional analysis, including the impacts on users (user benefits), air quality, accidents, security, severance, accessibility, labour market deepening, social cohesion, affordability and noise level. We suggest each impact needs to be further disaggregated for the identified social groups across the areas affected (impact area).

5.1.2 Method B: Status quo with more sensitivity analysis

Method B extends the status quo method by undertaking more analysis, using sensitivity and scenario analysis of a range of impacts. The scenarios we identified for further investigation of distributional impacts include:

- **Scenario 1 – baseline (MBCM):** This is the status quo method above, which we use as our baseline for comparisons with other scenarios. Note the parameter values within the benefit calculations are for the average person, applied in different transport situations.
- **Scenario 2 – extended scenario:** This scenario is to add measurements of benefits and disbenefits that are not included in scenario 1. The advantage of separating the two benefit totals is that scenario 1 provides a more certain and consistent benefit measure, while scenario 2 is expected to provide a fuller, but probably less accurate, estimate of total benefits.

  This scenario could be further generalised to take account of a range of non-MBCM analysis and uncertainty probing, beyond equity issues. It could also adjust scenario 1 for WTP to take account of any difference in the composition of the target population from the national population (from which the average WTPs were derived).
- **Scenario 3 – income weighting:** This scenario adjusts scenario 2 for the decreasing marginal utility from income, providing a standardised and simplified version of a welfare-weighted method. This scenario fundamentally differs from scenarios 1, 2 and 4 in that it does not necessarily imply a situation where compensation ensures a Pareto optimum could be achieved.
- **Scenario 4 – time effect:** To account for long-term health and environmental issues, this scenario applies a lower discount rate to scenario 2.

We recommended method B as the preferred method for the analysis of distributional effects. The advantage of a standardised four-scenario approach is it allows a transparent and consistent appraisal of projects and a more customised approach to CBA. It also allows a minimalist introduction of welfare weights into CBA.

5.1.3 Method C: Welfare weighted

Method C is used to apply income-adjusted weights. We used hypothetical examples to highlight difficulties with both measuring and interpreting the results of analysis using welfare weights. The use of welfare weights is particularly challenging because no universal acceptance has been reached of the appropriate weights, and it will be difficult for decision-makers to understand and compare welfare weighted net present values. For these reasons, instead of purely relying on a welfare-weighted method, we recommend including a standardised weighting process in method B as an additional scenario.

5.1.4 Method D: A bottom-up CBA based on accessibility and possibly capability building

We suggest method D provides a useful equity assessment framework. An advantage of this method is it ties CBA more closely to (a) the capabilities approach of the Treasury's LSF and (b) the accessibility measures that are increasingly being used for evaluation of transport appraisals across different countries (excluding New Zealand). We also discussed that the recent focus on accessibility as the outcome of transport intervention (instead of mobility) could provide further flexibility for using the outcome of an accessibility-based equity analysis with other assessments. Because of the advantages of this method, we suggest further exploration of the use of this method.

Despite the advantages of this method, we identified three major issues for adopting method D. First, method D's accessibility-based approach is inconsistent with the Waka Kotahi current mobility-based CBA approach. The second issue is with measuring the value of the provided accessibility for different socioeconomic groups, which requires a detailed assessment of WTP. The third issue is the lack of information on the appropriate measure of accessibility. We recommend further research on these three issues for using method D within the MBCM.

Because of the challenges of using method D, we suggest not pursuing that approach further in the current report until further information becomes available. However, we suggest method D provides a comprehensive framework for assessing distributional effects and should be further considered for 'long-term investments'.

Our analysis of the distributional impacts of the ATAP suggests relatively more benefits to higher-income groups.

We successfully applied the preferred method to a case study (ATAP) and identified various distributional impacts. Table 5.1 summarises the findings from the assessment of distributional effects across household income groups. Our overall results suggest a relatively high positive impact on the highest income group. The second highest impact is for the low–middle income group. Due to various measurement issues, we could not provide further information on distributional impacts for air quality, security, severance labour market deepening and social cohesion outcomes.

Table 5.1 Summary of the distributional analysis

Social group	Household income groups				
	1) $1–$30,000	2) $30,000–$70,000	3) $70,000–$100,000	4) $100,000–150,000	5) $150,000 or more
User benefits	✓✓	✓✓	✓✓	✓✓✓	✓✓
Air quality	–	–	–	–	–
Accidents	✓✓	✓	✓✓	✓✓	✓✓✓
Security	–	–	–	–	–
Severance	–	–	–	–	–
Accessibility	✓✓	✓✓	✓✓	✓✓	✓✓✓
Labour market deepening	–	–	–	–	–
Social cohesion	–	–	–	–	–
Affordability	✓✓✓	✓✓	✓✓	✓	✓

Source: Principal Economics

5.2 Recommended addition to Waka Kotahi monetised benefits and costs manual

The following is recommended as two additions to the MBCM.

First, a section should be appended to ‘1.2 Equity or distributional effects of land transport initiatives’ (between the current text and box) as follows.

‘An example of reporting benefit distribution is shown in Research Report <number to be confirmed>. This example is not intended as a prescriptive format. The analyst is to choose the reporting format appropriate to the nature of the distributional effect and the data available.

The extent of benefit distributional effects reported will inform whether further sensitivity testing for equity effects is appropriate. A recommended method for equity sensitivity testing is provided in section 7.2 <add link to section 7.2>’

Second, a section to be appended at the end of ‘7.2 Sensitivity tests’ as follows.

‘Equity or benefit distributional effects <heading>

Where benefit distributional effects are shown to be material then the following four methods (or scenarios) of reporting the present value of benefits are recommended.

Method 1. Standard method. Report the standard method, as per this manual, along with a report showing the quantification of distributional effects that was used to support the need for sensitivity testing.

Method 2. Non-standard benefit calculations. Append to method 1 any adjustments considered appropriate to the specific population affected by the transport initiative. Adjustments might include for effects not otherwise accounted for within this manual or for alternative forecast outcomes (eg induced demand) or for the affected population differing materially from the New Zealand average. Workings and references supporting the methods applied are required.

Method 3. Equity weighting. The current methods do not account for marginal wellbeing effects varying by the income of the population affected. Method 3 provides a crude but consistent method to adjust for declining marginal utility of income.

Step 1. Estimate the benefits/(disbenefits) by income bracket (eg, quintiles). This information is likely to be reported in method 1 (above).

Step 2. Estimate the WTP by income bracket where the benefit estimates are based on national averages (eg average value of travel time, average value of statistical life). The assumption made in this calculation is that WTP follows a square root relationship with income.

$$WTPi = WTP_{median} * SQRT(income_i)/SQRT(income_{median})$$

Where WTP_i = estimate WTP for income group i

WTP_{median} = national median WTP (applied in method 1)

$income_i$ = annual median household after-tax income for income group i

$income_{median}$ = annual national median after-tax household income

Step 3. Weight the WTP by income bracket according to the following formula.

$$wgtWTPi = WTP_i * ((income_{median} / income_i))^{1.3}$$

Where $wgtWTP_i$ = equity weighted WTP for income group i

And the 1.3 is the estimate of the marginal utility of income to apply

Step 4. Sum the equity weighted WTP for each income group to give the equity weighted benefit to report for the transport option under consideration.

Method 4. Intergenerational. Further importance is given to future generations by applying a longer period of analysis and lower discount rate. For consistency and transparency, the currently applied sensitivity tests employing a 60-year period and 3% per year discount rate are to be applied.'

5.3 Limitations and future research

A comprehensive distributional analysis needs to provide information on a range of impacts and socioeconomic groups. Our research project offered a solution that provides useful information on some distributional impacts. This gives analysts a robust process for identifying distributional impacts and reporting them, together with the rest of the analysis, to deliver comprehensive information for decision-makers. Further research is required to identify and measure the distributional effects of other impacts and account for the scenarios identified in our research project. This section provides further discussion and details on the limitations of our research and future topics on distributional analysis.

In identifying the preferred method, we also identified accessibility and enhanced-capability benefits (method D) as a comprehensive and useful method for considering equity effects. However, due to missing information, we suggest not pursuing method D until that information is available. Future studies should provide further information on:

- The use of accessibility in the Waka Kotahi MBCM. Currently, the MBCM adopts a mobility-based approach that is incompatible with the accessibility-based measurement required for method D. Further research is needed on the usefulness of replacing the mobility-based assessment with an accessibility-based method in the MBCM.
- Available measures of accessibility and their relevance to policy targets, including resilience and wellbeing.
- The WTP of different socioeconomic groups for improved accessibility using the identified measures. We suggest the current transport equity studies using method D do not account for the WTP. This is because they rely on Sen's capability approach (or a version of that) and argue that an equitable transport policy needs to provide access to all groups, without taking demand into consideration. We suggest a more useful approach would be to account for demand and the importance of accessibility to different socioeconomic groups.

Many physically, economically and socially disadvantaged people rely on walking and cycling for accessibility. We investigated this issue through sensitivity analysis using different measures of WTP. We also highlight the lack of data in Table E.1 and Table E.5 in Appendix E. Future studies should investigate the WTP further and provide the additional details required for the sensitivity analysis.

A comprehensive policy framework needs to account for the overlapping impacts of transport, housing and taxing policies. This is important because house prices (and housing costs) act as an aggregator of the value of access to amenities and facilities. With increases in the costs of housing, people with a lower affordability level move out, which leads to social exclusion. The current NPS-UD guidelines instruct councils to account for the availability of transport infrastructure in their assessment of housing and business development capacity (Ministry for the Environment, 2020). We suggest further investigation is done on the interactions between the current policy frameworks, particularly the GPS and NPS-UD, in achieving a 'well-functioning' urban form.

5.3.1 Limitations identified in our implementation of the preferred methodology – method B

For the analysis of distributional effects, we assumed the socioeconomic features of suburbs will not change over time. As discussed in section 2.2.3.1, impacts are likely on the choice of location from transport interventions. It is important to identify the likely changes in location of different socioeconomic groups and account for that in the analysis of distributional effects over time. We suggest future studies should investigate that further.

As discussed in section 4.3, a range of information was missing for a comprehensive assessment of distributional effects for different identified impacts. Tables E.1 to E.8 in Appendix E provide information on the issues identified in the literature relating to different socioeconomic groups and our solution for addressing them. The columns in each table show our scenarios: MBCM; Sc1 (disaggregation); Sc2a/Sc2b (WTP not recognised in MBCM); Sc3 (welfare weighted); and Sc4 (more weight to the next generation).

A limitation of our analysis is the unavailability of projections on the changes in socioeconomic features over time. In our analysis, we assumed the distribution of socioeconomic features across suburbs would remain at their Census 2018 levels. We suggest further investigation of potential solutions for providing projections of the socioeconomic features over time.

A future research topic is the integration of user benefits and accessibility. A useful output from the future accessibility study is to provide further information about the WTP of different income groups using a variety of accessibility measures. It is also important to provide clear guidance on the information contained in different measures of accessibility. Based on the identified measures and WTP estimates, the future study will provide important inputs for the adoption of method D identified in our study.

We did not have enough information for the measurement of severance and social cohesion impacts. While we recommend further analysis of distributional effects within these two impact areas, we also suggest it will be difficult to quantify these impacts.

Other ongoing research issues include measurements for various equity measures. This research could be conducted passively by Waka Kotahi as new methods are proposed by analysts under scenario 2 and/or done actively by Waka Kotahi-funded research.

5.3.2 Limitations of our distributional analysis of the case study (Auckland Transport Alignment Project)

An important caveat of our analysis is that we do not account for the impacts on new public transport users in the areas where public transport would not have been available in the Do Nothing scenario. This is because of the lack of information for calculating the changes in generalised costs and the short timeframe for our analysis. We suggest this caveat will affect our findings in areas in the south of Auckland.

Our analysis of the ATAP considered changes in mobility to work and education. This is because we did not have access to active mode data. Work and education trips often require private vehicle or public transport travel, but do not include activities that could be completed within a neighbourhood by walking and cycling.

Our case study illustrates applying the preferred distributional analysis method. Because the impact area of our case study is the Auckland region, the consideration of amenities in our qualitative assessment is difficult because of the range of amenities. Also, because of the regional focus of the ATAP programme, the variations we identified across social groups for different impact areas are small. Future studies could apply the preferred method to a project with a smaller impact area and highlight the distributional impacts for different social groups after accounting for amenities.

Our distributional analysis of the ATAP suggests the benefits are largely proportionate to the size of the population within each income group. Based on that and our investigation of the importance of welfare weights in our sensitivity analysis, we suggest that applying welfare weights to income groups in this case study does not materially change the final benefit measure. The future study of a project with a smaller impact area should provide further information about the importance of scenario 3 (welfare weights).

In our assessment of the safety impact of the ATAP, we assumed a 33 percent reduction in DSIs by 2031. In further discussions with Auckland Transport teams, they referred to the Programme Business Case of the ATAP and suggested the programme leads to a significantly higher emissions reduction by 67 percent. Our assessment, therefore, does not fully capture the safety impacts of the ATAP but provides an assessment of the safety implications associated with a change in trip making as a result of parts of the ATAP programme.

We also suggested various limitations with our affordability analysis of the ATAP. If our analysis would account for active mode, it is likely the results would capture further savings to lower-income households.

5.3.3 Further discussion

This report provides extensive discussion on the theoretical foundations, practical solutions and constraints for equity analysis of transport CBA appraisals.

Transportation planning decisions often have large and diverse effects on individual travellers and their communities. It is therefore important to understand the distribution of these impacts and whether they are considered equitable. This is an important issue, and practitioners – transport planners, engineers and modellers – have a responsibility to analyse these equity impacts to help decision-makers and the stakeholders they represent take them into account. This is an emerging issue; conventional transportation economic evaluation gives relatively little consideration to equity impacts, and the methods for analysing their impacts are still being developed.

This study reviews various transportation equity perspectives, impacts and evaluation methods, and evaluates ways they can be incorporated into existing economic evaluation practices, using the ATAP as a case study. The results indicate the existing model can be modified to analyse some equity impacts. However, because of the limitations of the current mobility-based transport CBA approach, the results tend to be limited to a set of perspectives and impacts in favour of mobility-oriented solutions (investments that increase vehicle travel speeds and distances) while undervaluing slower modes, demand management strategies and compact development. Additional research and data collection will be required before it is possible to apply comprehensive transportation equity analysis.

The arguments on ethical issues and equity are extensive. In this section, we refer to the objectives of a typical transportation equity analysis, as summarised by Litman (2022), and discuss the next steps required for achieving these objectives. One objective is for all parties to contribute to and receive comparable shares of public resources (typically measured per capita). To achieve this objective, we suggest further investigation of method D, which is more consistent with the capabilities approach. We argue that any assessment of accessibility improvement needs to be accompanied with an analysis of demand (using WTP).

Transport planning serves non-drivers as well as drivers. It is important for the distributional analysis to measure disparities in accessibility and mobility between drivers and non-drivers, and between people with various levels of physical ability. Our suggested methodology for distributional analysis considers the impacts on different social groups based on their presence in the impact area of transport investment. We also recommend further sensitivity analysis using different WTP measures. While this is a useful methodology, we are not aware of any source of information for further analysis of WTP for different socioeconomic groups.

Another objective of distributional analysis is to minimise external costs from congestion delays, crash risk and pollution damages. Our study offers guidance on the measurement of distributional analysis for user benefits, accidents and air quality. Some shortcomings occurred in measurement, such as for air quality, which we have highlighted for future research.

The affordable mobility and accessibility need to be investigated in the distributional analysis. This includes an evaluation of whether or not transportation is affordable, and whether transportation planning and investment decisions favour expensive travel options over affordable ones. In this study, we provide a method for assessing affordability outcomes. However, we have identified various shortcomings and highlight them for future research. Future research should also provide further discussion on the thresholds considered for transport being affordable. For example, households that spend less than 15 percent of their budgets on transport may be considered as a threshold for affordability. Broadly, our study provides a method for distributional analysis using the publicly available information. Further analysis using individual-level data, such as Stats NZ’s household economic survey, could provide more details on measurements required for distributional analysis.

References

Abulibdeh, A. (2013). *Equity implications of cordon pricing in downtown Toronto* [Doctoral thesis, University of Waterloo]. http://hdl.handle.net/10012/7202

Adler, M. D. (2016). Benefit–Cost analysis and distributional weights: An overview. *Review of Environmental Economics and Policy*, *10*(2), 264–285. https://doi.org/10.1093/reep/rew005

Adler, M. D. (2019). *Measuring social welfare: An introduction*. Oxford University Press.

Adli, S. N. (2019). *Inclusion of social justice in public transit planning: Development of a systematic framework for accessibility evaluation* [Doctoral thesis, University of Auckland]. http://hdl.handle.net/2292/53207

Adli, S. N., & Chowdhury, S. (2021). A critical review of social justice theories in public transit planning. *Sustainability*, *13*(8), 4289. https://doi.org/10.3390/su13084289

Adli, S. N., Chowdhury, S., & Shiftan, Y. (2019). Justice in public transport systems: A comparative study of Auckland, Brisbane, Perth and Vancouver. *Cities*, *90*, 88–99. https://doi.org/10.1016/j.cities.2019.01.031

Albuquerque, E. (2013). The NZ Transport Agency's transport appraisal framework. *Policy Quarterly*, *9*(4), 66–70. https://doi.org/10.26686/pq.v9i4.4472

Anciaes, P., & Jones, P. (2020). Transport policy for liveability – Valuing the impacts on movement, place, and society. *Transportation Research Part A: Policy and Practice*, *132*, 157–173. https://doi.org/10.1016/j.tra.2019.11.009

Anciaes, P. R., Jones, P., & Mindell, J. S. (2016). Community severance: Where is it found and at what cost? *Transport Reviews*, *36*(3), 293–317. https://doi.org/10.1080/01441647.2015.1077286

Annema, J. A., Mouter, N., & Razaei, J. (2015). Cost-benefit analysis (CBA), or multi-criteria decision-making (MCDM) or both: Politicians' perspective in transport policy appraisal. *Transportation Research Procedia*, *10*, 788–797.

Appleyard, B., Ferrell, C. E., Carroll, M. A., & Taecker, M. (2014). Toward livability ethics: A framework to guide planning, design, and engineering decisions. *Transportation Research Record: Journal of the Transportation Research Board*, *2403*(1), 62–71. https://doi.org/10.3141/2403-08

Arup. (2015). *Provision of market research for value of travel time savings and reliability. Phase 2 report.* Report to Department for Transport.

Åslund, O., Östh, J., & Zenou, Y. (2010). How important is access to jobs? Old question – improved answer. *Journal of Economic Geography*, *10*(3), 389–422. https://doi.org/10.1093/jeg/lbp040

Athira, I. C., Muneera, C. P., Krishnamurthy, K., & Anjaneyulu, M. V. L. R. (2016). Estimation of value of travel time for work trips. *Transportation Research Procedia*, *17*, 116–123. https://doi.org/10.1016/j.trpro.2016.11.067

Atkins. (2019). *Stubbington Bypass distributional impact report*. Report to Hampshire County Council.

Atkinson, J., Salmond, C., & Crampton, P. (2019). *NZDep2018 Index of Deprivation: Interim research report, December 2019*. University of Otago. https://www.otago.ac.nz/wellington/otago730394.pdf

Australian Government. (2020). *Distributional analysis*. The Office of Best Practice Regulation. https://obpr.pmc.gov.au/resources/guidance-assessing-impacts/distributional-analysis

AVV. (2000). *NVVP beleidsopties verkend [the National Traffic and Transport Policy options explored]*. AVV Transport Research Centre, Rotterdam.

Barfod, M. B., & Leleur, S. (2014). *Multi-criteria decision analysis for use in transport decision making* (2nd ed.). DTU Transport. https://backend.orbit.dtu.dk/ws/portalfiles/portal/104276012/DTU_Transport_Compendium_Part_2_MCDA_.pdf

Behbahani, H., Nazari, S., Jafari Kang, M., & Litman, T. (2019). A conceptual framework to formulate transportation network design problem considering social equity criteria. *Transportation Research Part A: Policy and Practice*, *125*, 171–183. https://doi.org/10.1016/j.tra.2018.04.005

Beria, P., Maltese, I., & Mariotti, I. (2012). Multicriteria versus cost benefit analysis: A comparative perspective in the assessment of sustainable mobility. *European Transport Research Review*, *4*(3), 137–152. https://doi.org/10.1007/s12544-012-0074-9

Beuthe, M. (2002). Transport evaluation methods: From cost–benefit analysis to multicriteria analysis and the decision framework. In L. Giorgi & A. Pearman (Eds.), *Project and policy evaluation in transport* (pp. 209–241). Ashgate.

Beyazit, E. (2011). Evaluating social justice in transport: Lessons to be learned from the capability approach. *Transport Reviews*, *31*(1), 117–134. https://doi.org/10.1080/01441647.2010.504900

Boardman, A. E. (2015). Cost–benefit analysis. In J. D. Wright (Ed.), *International encyclopedia of the social & behavioral sciences* (2nd ed., pp. 47–54). Elsevier. https://doi.org/10.1016/B978-0-08-097086-8.71068-3

Boardman, A. E. (2018). *Cost-benefit analysis: Concepts and practice* (5th ed.). Cambridge University Press.

Boardman, A. E., Greenberg, D. H., Vining, A. R. & Weimer, D. L. (2011). *Cost-benefit analysis concepts and practice* (4th ed). Cambridge University Press.

Boardman, A. E., Greenberg, D. H., Vining, A. R., & Weimer, D. L. (2020). Efficiency without apology: Consideration of the marginal excess tax burden and distributional impacts in benefit–cost analysis. *Journal of Benefit-Cost Analysis*, *11*(3), 457–478.

Bottoni, G. (2018). A multilevel measurement model of social cohesion. *Social Indicators Research*, *136*(3), 835–857. https://doi.org/10.1007/s11205-016-1470-7

Brent, R. J. (2006). *Applied cost–benefit analysis* (2nd ed). Edward Elgar.

Bristow, A. L., & Nellthorp, J. (2000). Transport project appraisal in the European Union. *Transport Policy*, *7*(1), 51–60. https://doi.org/10.1016/S0967-070X(00)00010-X

Browne, D., & Ryan, L. (2011). Comparative analysis of evaluation techniques for transport policies. *Environmental Impact Assessment Review*, *31*(3), 226–233. https://doi.org/10.1016/j.eiar.2010.11.001

Brussel, M., Zuidgeest, M., van den Bosch, F., Munshi, T., & van Maarseveen, M. (2019). Can the urban poor reach their jobs? Evaluating equity effects of relocation and public transport projects in Ahmedabad, India. In K. Lucas, K. Martens, F. Di Ciommo, & A. Dupont-Kieffer (Eds.), *Measuring transport equity* (pp. 85–109). Elsevier. https://doi.org/10.1016/B978-0-12-814818-1.00006-8

Cambridge Systematics, & Akin, Gump, Strauss, Hauer & Field. (2002). *Technical methods to support analysis of environmental justice issues*. Cambridge Systematics. https://www.somervillestep.org/files/TechMethodsAnalysisEnvJustice_0402.pdf

Cambridge University Press. (2011). Mitigation. In *Cambridge business English dictionary*.

Centre for Cities. (2021). Measuring up: Comparing public transport in the UK and Europe’s biggest cities.

Chadwick, N. (2021). *Leading light: What light rail can do for city regions*. Report prepared by Steer for Urban Transport Group. https://www.urbantransportgroup.org/resources/types/reports/leading-light-what-light-rail-can-do-city-regions

Creedy, J. (2006). *Evaluating policy: Welfare weights and value judgements* (Department of Economics Working Papers Series 971). University of Melbourne.

Curl, A., Watkins, A., McKerchar, C., Exeter, D., & Macmillan, A. (2020). *Social impact assessment of mode shift* (NZ Transport Agency research report 666). https://www.nzta.govt.nz/resources/research/reports/666

Currie, G. (2004). Gap analysis of public transport needs: Measuring spatial distribution of public transport needs and identifying gaps in the quality of public transport provision. *Transportation Research Record: Journal of the Transportation Research Board*, *1895*(1), 137–146. https://doi.org/10.3141/1895-18

Currie, G. (2010). Quantifying spatial gaps in public transport supply based on social needs. *Journal of Transport Geography*, *18*(1), 31–41. https://doi.org/10.1016/j.jtrangeo.2008.12.002

Currie, G., Richardson, T., Smyth, P., Vella-Brodrick, D., Hine, J., Lucas, K., Stanley, J., Morris, J., Kinnear, R., & Stanley, J. (2010). Investigating links between transport disadvantage, social exclusion and well-being in Melbourne – Updated results. *Research in Transportation Economics*, *29*(1), 287–295. https://doi.org/10.1016/j.retrec.2010.07.036

de Jong, G., Daly, A., Pieters, M., & van der Hoorn, T. (2007). The logsum as an evaluation measure: Review of the literature and new results. *Transportation Research Part A: Policy and Practice*, *41*(9), 874–889. https://doi.org/10.1016/j.tra.2006.10.002

de Jong, G., Pieters, M., Daly, A., Graafland, I., Kroes, E., & Koopmans, C. (2005). *Using the logsum as an evaluation measure: Literature and case study.* Prepared for AVV Transport Research Centre WR-275-AVV. RAND Europe.

de Jong, G., EXPEDITE Consortium, RAND Europe, Rand Corporation, & European Commission (Eds.). (2003). *EXPEDITE: EXpert-system based PrEdictions of demand for internal transport in Europe*. RAND.

Deboosere, R., & El-Geneidy, A. (2018). Evaluating equity and accessibility to jobs by public transport across Canada. *Journal of Transport Geography*, *73*, 54–63.

Delbosc, A., & Currie, G. (2011a). Using Lorenz curves to assess public transport equity. *Journal of Transport Geography*, *19*(6), 1252–1259. https://doi.org/10.1016/j.jtrangeo.2011.02.008

Delbosc, A., & Currie, G. (2011b). Exploring the relative influences of transport disadvantage and social exclusion on well-being. *Transport Policy*, *18*(4), 555–562. https://doi.org/10.1016/j.tranpol.2011.01.011

Dennig, F. (2018). Climate change and the re-evaluation of cost-benefit analysis. *Climatic Change*, *151*(1), 43–54.

Department of the Environment, Transport and the Regions. (2000). *Transport 2010. The background analysis.*

Department for Business, Energy & Industrial Strategy. (2018). *Warm Home Discount Scheme 2018 to 2019. Final stage impact assessment*. https://www.gov.uk/government/consultations/warm-home-discount-scheme-2018-to-2019

Department for Transport UK (DfT). (2020a). *TAG Unit A4.1 Social Impact Appraisal*. https://www.gov.uk/government/publications/tag-unit-a4-1-social-impact-appraisal

Department for Transport UK (DfT). (2020b). *TAG Unit A4.2 Distributional Impact Appraisal*. https://www.gov.uk/government/publications/tag-unit-a4-2-distributional-impact-appraisal

Di Ciommo, F., de la Hoz, D., & Guzman, L. A. (2014, 11–13 June). *Exploring users intertemporal preferences for measuring transport social equity effects* [Paper presentation]. PANAM Conference, Santader, Spain.

Di Ciommo, F., & Shiftan, Y. (2017). Transport equity analysis. *Transport Reviews*, *37*(2), 139–151. https://doi.org/10.1080/01441647.2017.1278647

Dobes, L., Leung, J., & Argyrous, G. (2016). *Social cost-benefit analysis in Australia and New Zealand: The state of current practice and what needs to be done*. ANU Press.

Dong, X., Ben-Akiva, M. E., Bowman, J. L., & Walker, J. L. (2006). Moving from trip-based to activity-based measures of accessibility. *Transportation Research Part A: Policy and Practice*, *40*(2), 163–180. https://doi.org/10.1016/j.tra.2005.05.002

Durie, M. (1999). Te Pae Māhutonga: A model for Māori health promotion. *Health Promotion Forum of New Zealand Newsletter*, 49.

El-Geneidy, A., Levinson, D., Diab, E., Boisjoly, G., Verbich, D., & Loong, C. (2016). The cost of equity: Assessing transit accessibility and social disparity using total travel cost. *Transportation Research Part A: Policy and Practice*, *91*, 302–316. https://doi.org/10.1016/j.tra.2016.07.003

Esteves, A. M., Franks, D., & Vanclay, F. (2012). Social impact assessment: The state of the art. *Impact Assessment and Project Appraisal*, *30*(1), 34–42. https://doi.org/10.1080/14615517.2012.660356

Exeter, D. J., Zhao, J., Crengle, S., Lee, A., & Browne, M. (2017). The New Zealand Indices of Multiple Deprivation (IMD): A new suite of indicators for social and health research in Aotearoa, New Zealand. *PLoS ONE*, *12*(8), e0181260. https://doi.org/10.1371/journal.pone.0181260

Farrington, J., & Farrington, C. (2005). Rural accessibility, social inclusion and social justice: Towards conceptualisation. *Journal of Transport Geography*, *13*(1), 1–12. https://doi.org/10.1016/j.jtrangeo.2004.10.002

Foth, N., Manaugh, K., & El-Geneidy, A. M. (2013). Towards equitable transit: Examining transit accessibility and social need in Toronto, Canada, 1996–2006. *Journal of Transport Geography*, *29*, 1–10. https://doi.org/10.1016/j.jtrangeo.2012.12.008

Fransen, K., & Farber, S. (2019). Using person-based accessibility measures to assess the equity of transport systems. In K. Lucas, K. Martens, F. Di Ciommo, & A. Dupont-Kieffer (Eds.), *Measuring transport equity* (pp. 57–72). Elsevier. https://doi.org/10.1016/B978-0-12-814818-1.00004-4

Freedman, J., Castiglione, J., & Charlton, B. (1981). Analysis of new starts project by using tour-based model of San Francisco, California. *Transportation Research Record*, *1981*(1), 24–33.

Fujiwara, D. (2010). *The Department for Work and Pensions Social Cost-Benefit Analysis framework: Methodologies for estimating and incorporating the wider social and economic impacts of work in cost-benefit analysis of employment programmes*. Department for Work and Pensions Working Paper No 86. http://research.dwp.gov.uk/asd/asd5/WP86.pdf

Gates, S., Gogescu, F., Grollman, C., Cooper, E., & Khambhaita, P. (2019). *Transport and inequality: An evidence review for the Department for Transport*. Department for Transport.

Geurs, K. T. (2018). *Transport planning with accessibility indices in the Netherlands* (International Transport Forum Discussion Papers No. 2018/09). https://doi.org/10.1787/c62be65d-en

Geurs, K. T., & van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: Review and research directions. *Journal of Transport Geography*, *12*(2), 127–140. https://doi.org/10.1016/j.jtrangeo.2003.10.005

Golub, A., & Martens, K. (2014). Using principles of justice to assess the modal equity of regional transportation plans. *Journal of Transport Geography*, *41*, 10–20. https://doi.org/10.1016/j.jtrangeo.2014.07.014

Gramlich, E. M. (1994). Infrastructure investment: A review essay. *Journal of Economic Literature*, *32*(3), 1176–1196.

Grant-Muller, S. (2004). *Study of policies regarding economic instruments complementing transport regulation and the undertaking of physical measures (SPECTRUM) deliverable 6*. http://www.its.leeds.ac.uk/projects/spectrum/downloads/D6.pdf

Grimes, A. (2019). *Wellbeing economic and policy: Past, present, future*. Presentation to RSNZ, Wanaka. https://www.wgtn.ac.nz/about/our-story/news-events/public-lecture-series/previous-lectures/public-lectures-2019/wellbeing-economics-and-policy-past,-present,-future

Groth, S. (2019). Multimodal divide: Reproduction of transport poverty in smart mobility trends. *Transportation Research Part A: Policy and Practice*, *125*, 56–71. https://doi.org/10.1016/j.tra.2019.04.018

Guers, K. (2020). *Accessibility and transport appraisal: Approaches and limitations* (International Transport Forum Discussion Papers No. 2020/22). https://doi.org/10.1787/58a96ff1-en

Gupta, S., Kalmanje, S., & Kockelman, K. M. (2006). Road pricing simulations: Traffic, land use and welfare impacts for Austin, Texas. *Transportation Planning and Technology*, *29*(1), 1–23. https://doi.org/10.1080/03081060600584130

Guzmán, L. A., Di Ciommo, F., & de la Hoz, D. (2013). Integration of congestion pricing and intertemporal preference rate in social welfare function. *Transportation Research Record: Journal of the Transportation Research Board*, *2346*(1), 1–12. https://doi.org/10.3141/2346-01

Henke, I., Cartenì, A., Molitierno, C., & Errico, A. (2020). Decision-making in the transport sector: A sustainable evaluation method for road infrastructure. *Sustainability*, *12*(3), 764. https://doi.org/10.3390/su12030764

Hickman, R., & Dean, M. (2018). Incomplete cost–incomplete benefit analysis in transport appraisal. *Transport Reviews*, *38*(6), 689–709. https://doi.org/10.1080/01441647.2017.1407377

HM Government. (2022). *Levelling up the United Kingdom*. Department for Levelling Up, Housing and Communities, UK.

HM Treasury. (2020). *Green book: Central government guidance on appraisal and evaluation.* https://www.webarchive.org.uk/access/resolve/20201125231833/https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938046/The_Green_Book_2020.pdf

Hyard, A. (2012). Cost-benefit analysis according to Sen: An application in the evaluation of transport infrastructures in France. *Transportation Research Part A: Policy and Practice*, *46*(4), 707–719. https://doi.org/10.1016/j.tra.2012.01.002

International Transport Forum (ITF). (2020). *Accessibility and transport appraisal: Summary and conclusions*. OECD Publishing.

Jara-Diaz, S. R. (1986). On the relation between users' benefits and the economic effects of transportation activities. *Journal of Regional Science*, *26*(2), 379–391. https://doi.org/10.1111/j.1467-9787.1986.tb00826.x

Jensen, K., & Thompson, C. (2020). Valuing Impacts: The contribution of CBAx to improved policy practices. *Policy Quarterly*, *16*(1), Article 1. https://doi.org/10.26686/pq.v16i1.6357

Johansson-Stenman, O. (1998). *The importance of ethics in environmental economics with a focus on existence values*. *Environmental & Resource Economics*, *11*(3), 429–442.

Johansson-Stenman, O. (2005). Distributional weights in cost-benefit analysis: Should we forget about them? *Land Economics*, *81*(3), 337–352.

Jones, P., & Lucas, K. (2012). The social consequences of transport decision-making: Clarifying concepts, synthesising knowledge and assessing implications. *Journal of Transport Geography*, *21*, 4–16. https://doi.org/10.1016/j.jtrangeo.2012.01.012

Kaplan, S., Popoks, D., Prato, C. G., & Ceder, A. (Avi). (2014). Using connectivity for measuring equity in transit provision. *Journal of Transport Geography*, *37*, 82–92. https://doi.org/10.1016/j.jtrangeo.2014.04.016

Karjalainen, L. E., & Juhola, S. (2021). Urban transportation sustainability assessments: A systematic review of literature. *Transport Reviews*, *41*(5), 659–684. https://doi.org/10.1080/01441647.2021.1879309

Kelobonye, K., McCarney, G., Xia, J. (Cecilia), Swapan, M. S. H., Mao, F., & Zhou, H. (2019). Relative accessibility analysis for key land uses: A spatial equity perspective. *Journal of Transport Geography*, *75*, 82–93. https://doi.org/10.1016/j.jtrangeo.2019.01.015

Kernohan, D., & Rognlien, L. (2011). *Wider economic impacts of transport investments in New Zealand* (NZ Transport Agency research report 448). https://www.nzta.govt.nz/resources/research/reports/448

Khisty, C. J. (1996). Operationalizing concepts of equity for public project investments. *Transportation Research Record*, *1559*(1), 94–99. https://doi.org/10.1177/0361198196155900112

Kolm, S. C. (1971). Justice et équité, Paris: Ed. du CNRS. Translated as *Justice and Equity*, Cambridge, Mass.: MIT Press, 2000.

Laird, J., & Mackie, P. J. (2009). *Review of economic assessment in rural transport appraisal*. Scottish Government Social Research.

Lefebvre, H. (1968). *Le droit à la ville*. Anthropos.

Levinson, D. (2002). Identifying winners and losers in transportation. *Transportation Research Record*, *1812*(1), 179–185. https://doi.org/10.3141/1812-22

Levinson, D. (2010). Equity effects of road pricing: A review. *Transport Reviews*, *30*(1), 33–57.

Lewis, E. O., MacKenzie, D., & Kaminsky, J. (2021). Exploring equity: How equity norms have been applied implicitly and explicitly in transportation research and practice. *Transportation Research Interdisciplinary Perspectives*, *9*, 100332. https://doi.org/10.1016/j.trip.2021.100332

Linneker, B. J., & Spence, N. A. (1992). Accessibility measures compared in an analysis of the impact of the M25 London Orbital Motorway on Britain. *Environment and Planning A: Economy and Space*, *24*(8), 1137–1154. https://doi.org/10.1068/a241137

Litman, T. (2022). *Evaluating transportation equity. Guidance for incorporating distributional impacts in transport planning.* Victoria Transport Policy Institute. https://www.vtpi.org/equity.pdf

Loeis, M., & Richardson, A. (1997). *Development of a welfare index for use in transport analysis and evaluation*. https://www.australasiantransportresearchforum.org.au/sites/default/files/1997_Loeis_Richardson.pdf

Lucas, K. (Ed.). (2004). *Running on empty: Transport, social exclusion and environmental justice*. Bristol University Press, Policy Press.

Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport Policy*, *20*, 105–113. https://doi.org/10.1016/j.tranpol.2012.01.013

Lucas, K., & Jones, P. (2012). Social impacts and equity issues in transport: An introduction. *Journal of Transport Geography*, *21*, 1–3. https://doi.org/10.1016/j.jtrangeo.2012.01.032

Lucas, K., Martens, K., Di Ciommo, F., & Dupont-Kieffer, A. (Eds.). (2019). *Measuring transport equity*. Elsevier.

Manaugh, K., Badami, M. G., & El-Geneidy, A. M. (2015). Integrating social equity into urban transportation planning: A critical evaluation of equity objectives and measures in transportation plans in North America. *Transport Policy*, *37*, 167–176. https://doi.org/10.1016/j.tranpol.2014.09.013

Marjanovic, S., Hanney, S., & Wooding, S. (2009). *A historical reflection on research evaluation studies, their recurrent themes and challenges*. RAND.

Martens, K. (2006). Basing transport planning on principles of social justice. *Berkeley Planning Journal*, *19*(1).

Martens, K. (2012). Justice in transport as justice in accessibility: Applying Walzer's 'Spheres of Justice' to the transport sector. *Transportation*, *39*(6), 1035–1053. https://doi.org/10.1007/s11116-012-9388-7

Martens, K. (2017). *Transport justice: Designing fair transportation systems*. Routledge.

Martens, K., Bastiaanssen, J., & Lucas, K. (2019). Measuring transport equity: Key components, framings and metrics. In K. Lucas, K. Martens, F. Di Ciommo, & A. Dupont-Kieffer (Eds.), *Measuring transport equity* (pp. 27–50). Elsevier.

Martens, K., & Di Ciommo, F. (2017). Travel time savings, accessibility gains and equity effects in cost–benefit analysis. *Transport Reviews*, *37*(2), 152–169. https://doi.org/10.1080/01441647.2016.1276642

Martens, K., Golub, A., & Robinson, G. (2012). A justice-theoretic approach to the distribution of transportation benefits: Implications for transportation planning practice in the United States. *Transportation Research Part A: Policy and Practice*, *46*(4), 684–695. https://doi.org/10.1016/j.tra.2012.01.004

Mella Lira, B. (2019). Using a capability approach-based survey for reducing equity gaps in transport appraisal: Application in Santiago de Chile. In K. Lucas, K. Martens, F. Di Ciommo, & A. Dupont-Kieffer (Eds.), *Measuring Transport Equity* (pp. 247–264). Elsevier. https://doi.org/10.1016/B978-0-12-814818-1.00016-0

Mieszkowski, P., & Mills, E. S. (1993). The causes of metropolitan suburbanization. *Journal of Economic Perspectives*, *7*(3), 135–147. https://doi.org/10.1257/jep.7.3.135

Ministry for the Environment. (2020). *Guidance on Housing and Business Development Capacity Assessments (HBAs) under the National Policy Statement on Urban Development.* https://environment.govt.nz/publications/guidance-on-housing-and-business-development-capacity-assessments-hbas-under-the-national-policy-statement-on-urban-development/

Ministry of Transport. (2014). *Adaptive investment management*. https://www.transport.govt.nz/assets/Uploads/Report/Adaptive-investment-management-real-options-approach-summary-report.pdf

Ministry of Transport. (2017). *Think piece – Use of adaptive management in ICT, transport, land use and housing*.

Ministry of Transport. (2020). *Auckland Transport Alignment Project 2021–2031 Investment Programme*. https://www.transport.govt.nz/assets/Uploads/Report/ATAP20212031.pdf

Ministry of Transport. (2021). *Auckland Transport Alignment Project 2021–2031*. https://www.transport.govt.nz//assets/Uploads/Report/ATAP_2021-31_Publication.pdf

Ministry of Transport, The Treasury, Auckland Council, State Services Commission, & NZ Transport Agency. (2016). *Auckland Transport Alignment Project recommended strategic approach*. https://www.transport.govt.nz/assets/Uploads/Report/ATAPRecommendedStrategicApproach.pdf

Mottee, L. K., Arts, J., Vanclay, F., Miller, F., & Howitt, R. (2020). Metro infrastructure planning in Amsterdam: How are social issues managed in the absence of environmental and social impact assessment? *Impact Assessment and Project Appraisal*, *38*(4), 320–335. https://doi.org/10.1080/14615517.2020.1741918

Mouter, N. (2021). Evaluation methods in transport policy and planning. *International Encyclopedia of Transportation*, 2021, 230–235. https://doi.org/10.1016/B978-0-08-102671-7.10645-1

MRCagney. (2020). *Equity in Auckland's transport system*. https://www.transport.govt.nz/assets/Uploads/Report/NZ3060_Equity_in_Auckland_Transport_System.pdf

Nahmias-Biran, B., Martens, K., & Shiftan, Y. (2017). Integrating equity in transportation project assessment: A philosophical exploration and its practical implications. *Transport Reviews*, *37*(2), 192–210. https://doi.org/10.1080/01441647.2017.1276604

Nahmias-Biran, B., Sharaby, N., & Shiftan, Y. (2014). Equity aspects in transportation projects: Case study of transit fare change in Haifa. *International Journal of Sustainable Transportation*, *8*(1), 69–83. https://doi.org/10.1080/15568318.2012.758525

Nahmias-Biran, B., & Shiftan, Y. (2016). Towards a more equitable distribution of resources: Using activity-based models and subjective well-being measures in transport project evaluation. *Transportation Research Part A: Policy and Practice*, *94*, 672–684. https://doi.org/10.1016/j.tra.2016.10.010

Nahmias-Biran, B., & Shiftan, Y. (2019). Using activity-based models and the capability approach to evaluate equity considerations in transportation projects. *Transportation*, *47*(5), 2287–2305. https://doi.org/10.1007/s11116-019-10015-9

Nazari Adli, S., & Donovan, S. (2018). Right to the city: Applying justice tests to public transport investments. *Transport Policy*, *66*, 56–65. https://doi.org/10.1016/j.tranpol.2018.03.005

New Zealand Government. (2020). *Government Policy Statement on Land Transport 2021/22–2030/31*. https://www.transport.govt.nz/assets/Uploads/Paper/GPS2021.pdf

New Zealand Institute of Economic Research (NZIER). (2018). *Review of CBA advice to support budget initiatives: The impact of CBAx and lessons for future budget processes.* NZIER report to the Treasury. https://www.treasury.govt.nz/publications/review-cba-advice-support-budget-initiatives-nzier-report-treasury

New Zealand Treasury. (2015). *Guide to social cost benefit analysis*. https://www.treasury.govt.nz/publications/guide/guide-social-cost-benefit-analysis

New Zealand Treasury. (2021). *The Living Standards Framework (LSF) 2021*. https://www.treasury.govt.nz/publications/tp/living-standards-framework-2021-html

Nunns, P., Whitaker, E., & Donovan, S. (2019). *Social and distributional impacts of time and space-based road pricing* (NZ Transport Agency Research Report 654). https://www.nzta.govt.nz/resources/research/reports/654

Nussbaum, M. (1997). Capabilities and human rights. *Fordham Law Review*, *66*(2), 273–299.

Nussbaum, M. (2000). *Women and human development the capabilities approach*. Cambridge University Press.

Nussbaum, M. (2007). Human rights and human capabilities. *Harvard Human Rights Journal*, *20*, 21–24.

NZ Transport Agency. (2016). *Social impact guide*. https://www.nzta.govt.nz/assets/resources/guide-to-assessing-social-impacts-for-state-highway-projects/16-243-People-and-place-state-highway-social-impact-guide-2017-FINAL.pdf

NZ Transport Agency. (2018). *Economic evaluation manual*. https://www.nzta.govt.nz/resources/economic-evaluation-manual

NZ Transport Agency. (2020). *Monetised benefits and cost manual*. https://www.nzta.govt.nz/resources/monetised-benefits-and-costs-manual/

Odgaard, T., Kelly, C. E., & Laird, J. (2006). *Current practice in project appraisal in Europe.* HEATCO.

OECD. (2002). *Policy instruments for achieving environmentally sustainable transport*. https://doi.org/10.1787/9789264176249-en

Pardo, C. F., Jiemian, Y., Hongyuan, Y., & Mohanty, C. R. (2012). *Shanghai manual: A guide for sustainable urban development in the 21st century*. The Commercial Press.

Pereira, R. H. M., Banister, D., Schwanen, T., & Wessel, N. (2018). Distributional effects of transport policies on inequalities in access to opportunities in Rio de Janeiro. *Journal of Transport and Land Use, 12*(1), https://doi.org/10.5198/jtlu.2019.1523

Pereira, R. H. M., Schwanen, T., & Banister, D. (2017). Distributive justice and equity in transportation. *Transport Reviews*, *37*(2), 170–191. https://doi.org/10.1080/01441647.2016.1257660

Pike, R. (2015). *Corporate finance and investment: Decisions and strategies* (8th ed.). Pearson.

Qi, Z., Lim, S., & Hossein Rashidi, T. (2020). Assessment of transport equity to Central Business District (CBD) in Sydney, Australia. *Transportation Letters*, *12*(4), 246–256. https://doi.org/10.1080/19427867.2019.1584694

Radbone, I. (1994). Taking social justice seriously in the provision of public transport. In *Papers of the 19th Australasian Transport Research Forum* (Vol. 19, pp. 133–148). University of Melbourne.

Rahman, A., & van Grol, R. (2005). *SUstainable Mobility, policy Measures and Assessment (SUMMA) Final Report*. European Commission.

Ramjerdi, F. (2006). Equity measures and their performance in transportation. *Transportation Research Record*, *1983*(1), 67–74. https://doi.org/10.1177/0361198106198300110

Randal, E., Shaw, C., Woodward, A., Howden-Chapman, P., Macmillan, A., Hosking, J., Chapman, R., Waa, A. M., & Keall, M. (2020). Fairness in transport policy: A new approach to applying distributive justice theories. *Sustainability*, *12*(23), 10102. https://doi.org/10.3390/su122310102

Raux, C., & Souche, S. (2004). The acceptability of urban road pricing: A theoretical analysis applied to experience in Lyon. *Journal of Transport Economics and Policy*, *38*(2), 191–215.

Rawls, J. (1999). *A theory of justice* (Rev. ed). Belknap Press of Harvard University Press.

Rietveld, P. (2003). *Winners and losers in transport policy: On efficiency, equity, and compensation*. D. A. Hensher & K. J. Button (Eds.), *Handbook of transport and the environment* (pp. 585–601). Emerald Group. https://doi.org/10.1108/9781786359513

Roback, J. (1982). Wages, rents, and the quality of life. *Journal of Political Economy*, *90*(6), 1257–1278. https://doi.org/10.1086/261120

Rofé, Y., Benenson, I., Martens, K., Ben-Elia, E., & Mednik, N. (2015). *Accessibility and social equity in Tel-Aviv metropolitan area – Examination of the current conditions and development scenarios*. Department of Geography & Environmental Development, The Swiss Institute for Dryland Environmental and Energy Research.

Rowangould, D., Karner, A., & London, J. (2016). Identifying environmental justice communities for transportation analysis. *Transportation Research Part A: Policy and Practice*, *88*, 151–162. https://doi.org/10.1016/j.tra.2016.04.002

Sanchez, T. W., Stolz, R., & Ma, J. S. (2003). *Moving to equity: Addressing inequitable effects of transportation policies on minorities.* The Civil Rights Project at Harvard University.

Schiefer, D., & van der Noll, J. (2017). The essentials of social cohesion: A literature review. *Social Indicators Research*, *132*(2), 579–603. https://doi.org/10.1007/s11205-016-1314-5

Schumpeter, J. A. (1949). Vilfredo Pareto (1848–1923). *The Quarterly Journal of Economics*, *63*(2), 147. https://doi.org/10.2307/1883096

Sdoukopoulos, A., Pitsiava-Latinopoulou, M., Basbas, S., & Papaioannou, P. (2019). Measuring progress towards transport sustainability through indicators: Analysis and metrics of the main indicator initiatives. *Transportation Research Part D: Transport and Environment*, *67*, 316–333. https://doi.org/10.1016/j.trd.2018.11.020

Searle, G. & Legacy, C. (2019). Australian mega transport business cases: Missing costs and benefits. *Urban Policy and Research*, *37*(4), 458–473.

Sen, A. (1999). *Development as freedom* (1st. ed). Knopf.

Shang, J. S., Tjader, Y., & Ding, Y. (2004). A unified framework for multicriteria evaluation of transportation projects. *IEEE Transactions on Engineering Management*, *51*(3), 300–313. https://doi.org/10.1109/TEM.2004.830848

Sheller, M. (2018). *Mobility justice: The politics of movement in an age of extremes*. Verso Books.

Shiftan, Y., Sharav, N., Shiftan, Y., & Martens, K. (2021). *Accounting for equity in transport appraisal*. International Transport Forum. https://www.itf-oecd.org/accounting-equity-transport-planning

Shortall, R., & Mouter, N. (2021). Social and distributional impacts in transport project appraisals. In R. H. M. Pereira, G. Boisjoly (Eds.), *Advances in transport policy and planning* (Vol. 8, pp. 243–271). Elsevier.

Silber, J. (Ed.). (1999). *Handbook of income inequality measurement*. Springer. https://doi.org/10.1007/978-94-011-4413-1

Social Exclusion Unit. (2003). *Making the connections: Final report on transport and social exclusion*.

Soja, E. W. (2010). *Seeking spatial justice*. University of Minnesota Press.

South Australian Government. (2003). *South Australia's draft transportation plan: Towards a sustainable transport future*.

Stanley, J. K., Hensher, D. A., Wei, E., & Liu, W. (2021). Major urban transport expenditure initiatives: Where are the returns likely to be strongest and how significant is social exclusion in making the case. *Research in Transportation Business & Management*, 100731. https://doi.org/10.1016/j.rtbm.2021.100731

Stroombergen, A., Bealing, M., Torshizian, E., & Poot, J. (2018). *Impacts of socio-demographic changes on the New Zealand land transport system* (NZ Transport Agency research report 646). https://www.nzta.govt.nz/resources/research/reports/646

Stroombergen, A., Byett, A., Maré, D., & Fabling, R. (2021). *Accessibility: Its role and impact on labour and housing markets in New Zealand's main metropolitan areas* (NZ Transport Agency research report 682). https://nzta.govt.nz/resources/research/reports/682/

Sultana, S., Salon, D., & Kuby, M. (2019). Transportation sustainability in the urban context: A comprehensive review. *Urban Geography*, *40*(3), 279–308. https://doi.org/10.1080/02723638.2017.1395635

Thomopoulos, N., Grant-Muller, S., & Tight, M. R. (2009). Incorporating equity considerations in transport infrastructure evaluation: Current practice and a proposed methodology. *Evaluation and Program Planning*, *32*(4), 351–359. https://doi.org/10.1016/j.evalprogplan.2009.06.013

Thomopoulos, N., Grant-Muller, S., & Tight, M. R. (2013). Incorporating equity as part of the wider impacts in transport infrastructure assessment: An application of the SUMINI approach. *Transportation*, *40*(2), 315–345. https://doi.org/10.1007/s11116-012-9418-5

Torshizian, E. (2017). *Effects of crowding, density and deprivation on residential satisfaction* [Doctoral dissertation, University of Auckland]. http://hdl.handle.net/2292/32620

Torshizian, E. (2019). *Using big data and economics to understand and improve wellbeing*. New Zealand Institute of Economic Research (NZIER).

Torshizian, E. (2020). *Shaping future Dunedin transport PBC – Estimation of the wider economic benefits*. https://nzta.govt.nz/assets/projects/shaping-future-dunedin-transport/SFDT-programme-business-case.pdf

Torshizian, E., & Grimes, A. (2014). *Residential satisfaction, crowding and density: Evidence over different geographic scales in Auckland*. https://www.nzae.org.nz/wp-content/uploads/2015/01/Residential_Satisfaction_Crowding_and_Density_ET.pdf

Torshizian, E., & Isack, E. (2020). *Fair fare for public transport*. Auckland Transport.

Transport and Infrastructure Council. (2016). *Australian transport assessment and planning guidelines – T5 distributional (equity) effects*. https://www.atap.gov.au/sites/default/files/t5_distributional_equity_effects.pdf

Transportation Research Board & National Academies of Sciences, Engineering, and Medicine. (2004). *Effective methods for environmental justice assessment*. Transportation Research Board. https://doi.org/10.17226/13694

Tsoukiàs, A. (2008). From decision theory to decision aiding methodology. *European Journal of Operational Research*, *187*(1), 138–161.

van Wee, B. (2016). Accessible accessibility research challenges. *Journal of Transport Geography*, *51*, 9–16. https://doi.org/10.1016/j.jtrangeo.2015.10.018

van Wee, B., & Geurs, K. (2011). Discussing equity and social exclusion in accessibility evaluations. *European Journal of Transport and Infrastructure Research*, *11*(4). https://doi.org/10.18757/EJTIR.2011.11.4.2940

van Wee, B., & Mouter, N. (2021). Evaluating transport equity. *Advances in Transport Policy and Planning*, *7*, 103–126.

Vanclay, F. (2003). International principles for social impact assessment. *Impact Assessment and Project Appraisal*, *21*(1), 5–12. https://doi.org/10.3152/147154603781766491

Vecchio, G., & Martens, K. (2021). Accessibility and the capabilities approach: A review of the literature and proposal for conceptual advancements. *Transport Reviews*, *41*(6), 833–854. https://doi.org/10.1080/01441647.2021.1931551

Waka Kotahi NZ Transport Agency. (in press). *Monetised benefits and costs manual (MBCM) parameter values: Results of a survey to derive values for road safety, travel time and reliability*.

Waka Kotahi NZ Transport Agency. (2020). *Multi-criteria assessment: User guidance*. https://www.nzta.govt.nz/assets/resources/planning-policy-manual/docs/multi-criteria-assessment-user-guidance.pdf

Waka Kotahi NZ Transport Agency. (2021a). *Access to key social destinations (NLTP App)*. https://experience.arcgis.com/experience/5707b92a8bd042e3a4a4750164117e66

Waka Kotahi NZ Transport Agency. (2021b). *Monetised benefits and costs manual* (v1.5). https://www.nzta.govt.nz/resources/monetised-benefits-and-costs-manual/

Wallis, I. (2009). *Economic development benefits of transport investment* (Land Transport NZ research report 350). https://www.nzta.govt.nz/resources/research/reports/350

Walzer, M. (1984). *Spheres of justice: A defence of pluralism and equality*. Basic Books.

Waters, W. G. (1994). The value of travel time savings and the link with income: Implications for public project evaluation. *International Journal of Transport Economics / Rivista Internazionale Di Economia Dei Trasporti*, *21*(3), 243–253.

Appendix A: Equity types

Table A.1 Equity types and principles

Equity type	Features
Horizontal equity	Comparable individuals, groups or regions should be treated in a comparable way
Vertical equity	Disadvantaged individuals, groups or regions deserve protection. People should be burdened according to their ability to contribute, and this may lead to schemes where taxes may be progressive
Territorial equity	Results from the notion of individual equity, when it is projected on relatively homogeneous regions, and the need to get similar funds for (public) transport
Territorial cohesion	Refers to balanced development of human activities across the European Union
Level playing field	Transport sectors should be treated in similar ways according to taxation, payment for the use of infrastructure and so on
Transport users should pay their way	This concept is usually interpreted in terms of average costs implying that the collective of all transport users exactly pays for the aggregate costs
Individuals who are negatively affected by policies need to be compensated	This principle has its starting point in the status-quo situation, and implies that winners have to compensate losers
Egalitarianism	All individuals are treated equally, making the same contribution, disregarding their financial (or other) ability
Spatial equity	Refers to the geographical location of an individual, group or region affected by a transport infrastructure project
Social equity	Refers to the impact on personal, economic or social characteristics of an individual, group or region
Solidarity	It is anticipated that an increased focus on solidarity issues will be facilitated by setting the European Union transport policy in the context of the wider European Union cohesion policy

Source: Adapted from Thomopoulos et al. (2009, p. 356)

Appendix B: Mathematical formulation of different social equity approaches

As discussed in section 2.2.4.1, this section contains the mathematical formulations corresponding to different social equity problems in infrastructure investment. Table B.1 provides information about the mathematical formulations, as suggested by Behbahani et al. (2019).

Table B.1 Mathematical formulations for different equity theories

Scenario	Equity theory	The school of thought behind the approach	The considered criteria of the approach	Motivation
A	Utilitarianism	Utilitarian Liberalism, Scholastic Philosophy	$Max \sum_i Ac_i$	To Maximize the Total Final Benefits (Utilities) of the Society
B	Rawls's theory of Justice	John Rawls	$Max \sum_k Ac_k$ $k \in P$ (P: the poorest group)	To Maximize the Total Final Benefits of the Poorest Group of the Society
C	Egalitarianism	Socialism	$Min \frac{\sum_i \sum_j \mid Ac_i - Ac_j \mid}{2n^2 \overline{Ac}}$	To Maximally Achieving Equality in the Final Benefits, Using Unequal Distribution of Added Benefits in the Community
D	Equal Sharing	Socialism	$Min \frac{\sum_i \sum_j \mid \Delta Ac_i - \Delta Ac_j \mid}{2n^2 \overline{\Delta Ac}}$	To Maximally Achieving Equality in the Distribution of Added Benefits in the Community
E	Narrowing the Gap in Final Benefits	Socialism, Deontological Liberalism, Sadr	$Max \sum_i Ac_i$ $s.\ t.:$ $Ac_i > m_1 * Ac_j \ \forall \ i,j$	To Maximize the Total Final Benefits, with the Consideration of Narrowing the Gap in Final Benefits of the Groups in the Community
F	Limiting the Variance in Added Benefits	Socialism, Deontological Liberalism, John Rawls, Sadr	$Max \sum_i Ac_i$ $s.\ t.:$ $\Delta Ac_i > m_2 * \Delta Ac_j \ \forall \ i,j$	To Maximize the Total Final Benefits, with the Consideration of Limiting the Variance in Added Benefits For All Groups in the Community (to Protect the Poor)
G	Sadr's theory of Justice	Sadr	$Max \sum_i Ac_i$ $s.t.:$ $Ac_i > m_3 * Ac_j \ \forall \ i,j$ $\frac{\sum_i \sum_j \mid Ac_i - Ac_j \mid}{2n^2 \overline{Ac}} < m_4$	To Maximize the Total Final Benefits of the Society, while Ensuring a Minimum Final Benefit for the Poorest Group, and Narrowing the Gap in Total Final Benefits

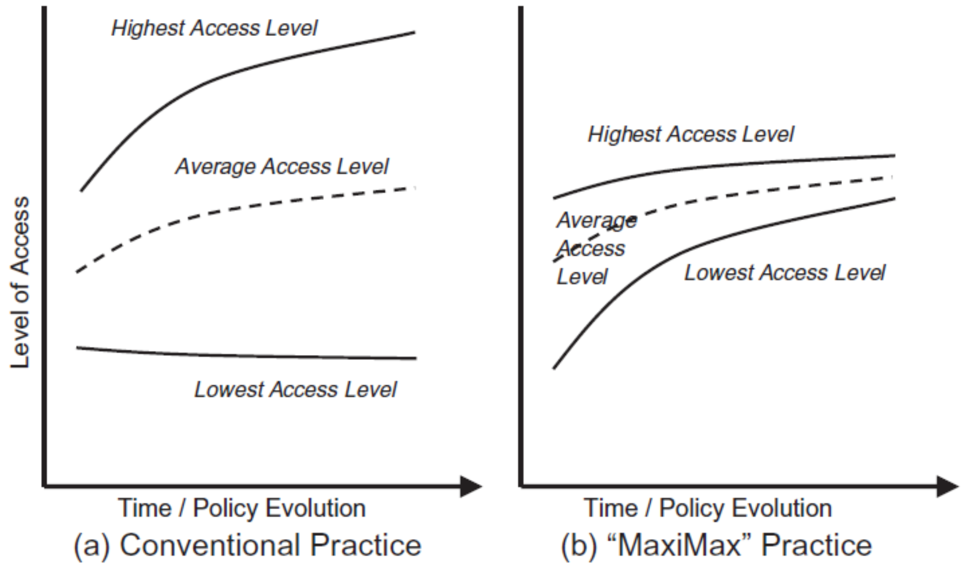
where:
Ac_i, distributable benefit for the group i,
$\overline{Ac}$, the average of Ac,
n, number of groups,
ΔAc_i, added benefits for the Group i,
m_1, m_2, m_3, & m_4, the gap parameters.

Source: Reprinted from Behbahani et al. (2019, p. 8)

Appendix C: Equity impacts discussions

Martens (2012) refers to Walzer's (1984) *Spheres of Justice* and suggests transport equity should be considered in isolation from the distribution of other goods based on its 'spheres of influence'. This follows the idea that similar 'goods', such as education and health care, belong to different distributive 'spheres' of society. He suggests two potential principles relevant for transport distribution: (1) maximising the average accessibility level with a floor constraint for the minimum; and (2) maximising the average accessibility level with a range constraint. The latter, which he refers to as 'maximax', differs in that the minimum floor automatically adjusts based on the upper bound of accessibility. Figure C.1 shows the theoretical impact of the 'maximax' principle on accessibility compared with conventional practice.

Figure C.1 Maximax principle



Source: Reprinted from Martens et al. (2012, p. 291)

Adli et al. (2019) propose a justice framework specific to transit planning (as opposed to including all transportation modes), noting scheduling and spontaneity as the main point of difference between public and private transit.

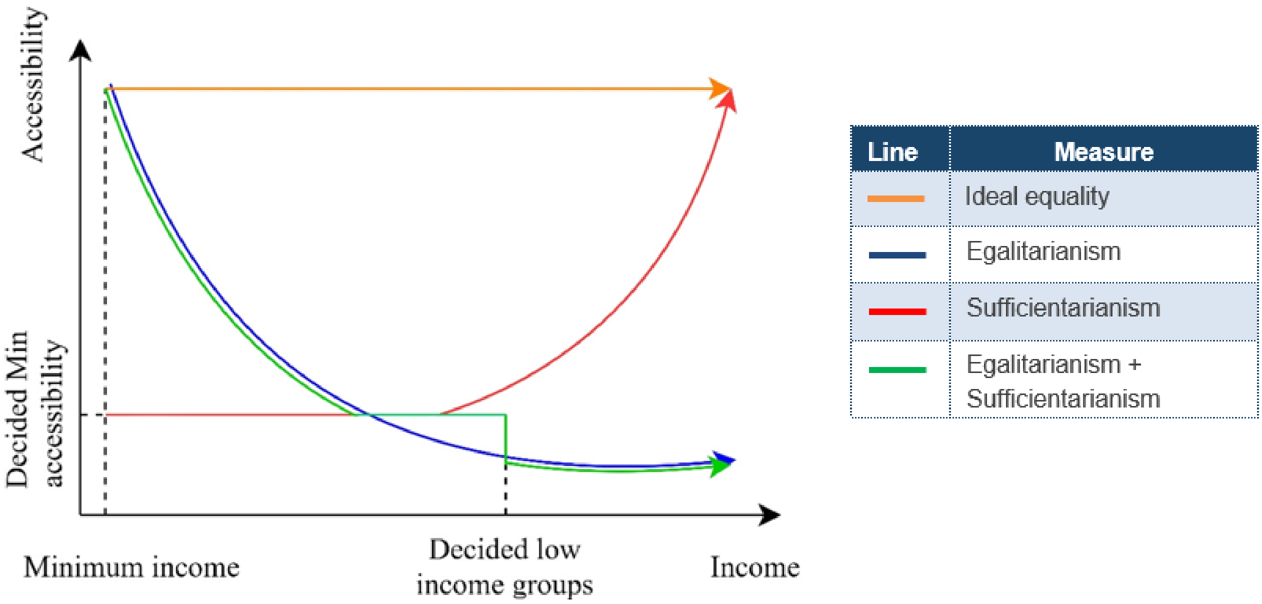
> *Transit must exist in both space and time thus it must run not just where we need it but also when we need it. Unless it does both, it does not exist for us at all.* (Adli et al., 2019, p. 89)

They propose an evaluation framework following egalitarian and sufficientarian notions whereby transit services are prioritised to provide a minimum level of accessibility to low-income and low-accessible areas, and accessibility benefits should benefit least well-off groups. Adli et al. (2019) suggest a framework that can identify transit-deprived areas across the time travel dimension. Additionally, the framework focuses on ranking the distribution of transit services taking a comparative approach to justice aligning with Sen's capability framework.

Adli et al. (2019) provide a chart (see Figure C.2) illustrating the distribution of accessibility versus income under different transit equity approaches. The orange line shows the ideal equality where everyone has high accessibility. The blue line shows egalitarianism views where low income receives better accessibility. Red shows sufficientarianism views, where the focus is only on provision of a minimum level of accessibility.

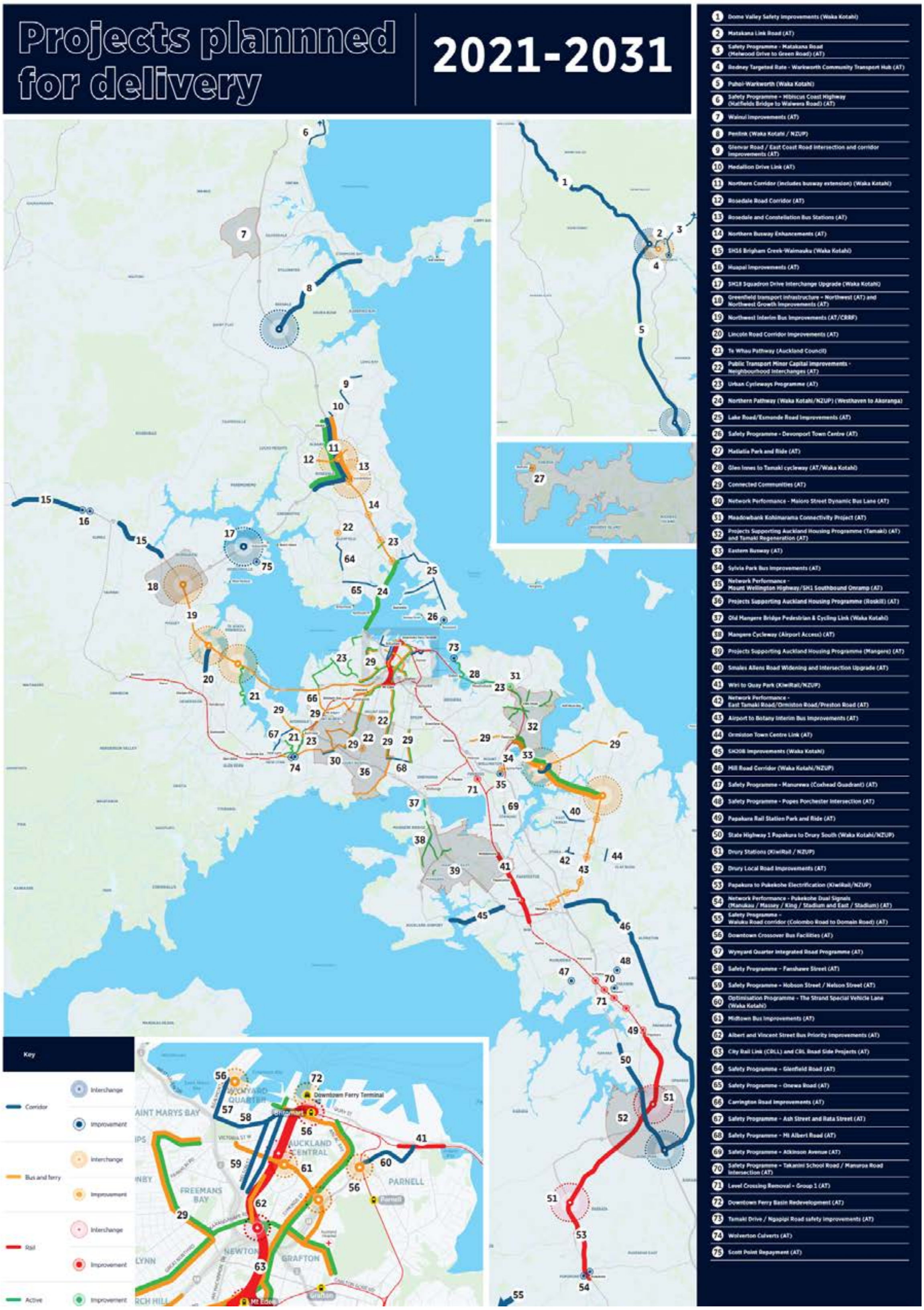
Green shows the proposed approach by Adli et al. (2019) combining egalitarianism and sufficientarianism views.

Figure C.2 Accessibility versus income under different equity approaches



Source: Adapted from Adli et al. (2019, p. 90)

Appendix D: Auckland Transport Alignment Project – projects planned for delivery by 2031



Appendix E: Issues identified in implementation of method B

Table E.1 to Table E.8 in this appendix provide information on the issues identified in literature relating to different socioeconomic groups and our solution for addressing them. The columns in each table show our scenarios: MBCM; Sc1 (disaggregation); Sc2a/Sc2b (WTP not recognised in MBCM); Sc3 (welfare weighted); and Sc4 (more weight to the next generation).

Table E.1 Issues identified in the literature relating to low-income groups

Impact (source)	Low-income households	Sc1	Sc2a/Sc2b	Sc3	Sc4	Comment
		MBCM	EXTENDED	WELFARE	LENGTHENED	
User benefits (DfT TAG 4.1/4.2)	Y	Y		Y	?	Benefits measured (user and non-user) disaggregated by five income groups (Sc1). Note, Auckland has relatively more high-income people. Crude social welfare weights also applied (Sc3).
Noise (DfT TAG 4.1/4.2)	Y					Noise measures were not made available for this case study. No analysis undertaken.
Air quality (DfT TAG 4.1/4.2)	Y	Limited		Y	Y	Approximate from VOC benefits made (no previous analysis provided). Benefits disaggregated by income group (Sc1). Crude social welfare weights applied (Sc3). More weight put on intergenerational issues (Sc4).
Personal affordability (DfT TAG 4.1/4.2)	Y	Limited		Y		VOC and public transport fares disaggregated by five income groups (Sc1).
Option values	Y					Insufficient data and time to assess. No analysis undertaken.
Visual quality/ decreases in value of non-acquired property	Y					Insufficient data and time to assess. No analysis undertaken.
Localised air pollution	Y					Insufficient data and time to assess. No analysis undertaken.

Impact (source)	Low-income households	Sc1	Sc2a/Sc2b	Sc3	Sc4	Comment
		MBCM	EXTENDED	WELFARE	LENGTHENED	
Availability and physical access to the transport system	Y	Limited				Disaggregation by disability and zone calculated but insufficient data for further analysis.
Public safety	Y					Insufficient data and time to assess. No analysis undertaken.
Water and soil quality	Y					Insufficient data and time to assess. No analysis undertaken.
Labour market deepening	Y	Maybe	Maybe			Potentially could consider modelled trips versus extra accessibility. Insufficient data and time to assess. No analysis undertaken.
Reduced cost of housing from increased access to peri-urban land	Y	Maybe				Potentially could consider benefit distribution on periphery. Insufficient data and time to assess. No analysis undertaken.

Source: Principal Economics

Note: DfT = Department for Transport; MBCM = Waka Kotahi monetised benefits and costs manual; TAG = transport analysis guidance; VOC = vehicle operating costs.

Table E.2 Issues identified in the literature relating to children

Impact (source)	Children (<16)	Sc1	Sc2a/Sc2b	Sc3	Sc4	Comment
		MBCM	EXTENDED	WELFARE	LENGTHENED	
Noise (DfT TAG 4.1/4.2)	Y					Noise measures were not made available for this case study. No analysis undertaken.
Air quality (DfT TAG 4.1/4.2)	Y	Limited		Y	Y	Approximate from VOC benefits made (no previous analysis provided). Benefits disaggregated by income group (Sc1). Crude social welfare weights applied (Sc3). More weight put on intergenerational issues (Sc4).
Accidents (DfT TAG 4.1/4.2)	Y	Y	Considered but not applied	Y	Y	DSI disaggregated by children and zone (not actual crashes), plus other disaggregation (Sc1). WTP elasticity to income changes over time added (not specific to children but

Impact (source)	Children (<16)	Sc1	Sc2a/Sc2b	Sc3	Sc4	Comment
		MBCM	EXTENDED	WELFARE	LENGTHENED	
						acknowledged of longer-term effects). Considered higher WTP for children but research inconclusive (Sc2). Welfare weights and lower discount rates applies (Sc3, Sc4).
Security (DfT TAG 4.1/4.2)	Y					Insufficient data and time to assess. No analysis undertaken.
Severance (DfT TAG 4.1/4.2)	Y					Insufficient data and time to assess. No analysis undertaken.
Accessibility (DfT TAG 4.1/4.2)	Y	Limited				User benefits disaggregated by children and zone, plus other disaggregation (Sc1). Note, Auckland has a similar proportion of children to the New Zealand population but a higher proportion of households with dependants.

Source: Principal Economics

Note: DfT = Department for Transport; DSI = death and serious injury; MBCM = Waka Kotahi monetised benefits and costs manual; TAG = transport analysis guidance; VOC = vehicle operating costs; WTP = willingness to pay.

Table E.3 Issues identified in the literature relating to young adults

Impact (source)	Young adults (16–25)	Sc1	Sc2a/Sc2b	Sc3	Sc4	Comment
		MBCM	EXTENDED	WELFARE	LENGTHENED	
Accessibility (DfT TAG 4.1/4.2), including for spatially distributed activities	Y	Limited				User benefits for different purposes disaggregated by age groups (Sc1).
Accidents (DfT TAG 4.1/4.2)	Y	Y		Y	Y	DSI disaggregated by youth and zone (not actual crashes), plus other disaggregation (Sc1). WTP elasticity to income changes over time added (not specific to children but acknowledged of longer-term effects) (Sc2). Welfare weights and lower discount rates applies (Sc3, Sc4).
Personal affordability (DfT TAG 4.1/4.2)	Y	Limited		Y		VOC and (maybe) public transport fares disaggregated by age (and other groups) (Sc1).

Impact (source)	Young adults (16–25)	Sc1	Sc2a/Sc2b	Sc3	Sc4	Comment
		MBCM	EXTENDED	WELFARE	LENGTHENED	
Labour market deepening	Y	Maybe				Potentially could consider modelled trips versus extra accessibility. Insufficient data and time to assess. No analysis undertaken.

Source: Principal Economics

Note: DfT = Department for Transport; DSI = death and serious injury; MBCM = Waka Kotahi monetised benefits and costs manual; TAG = transport analysis guidance; VOC = vehicle operating costs; WTP = willingness to pay.

Table E.4 Issues identified in the literature relating to older people

Impact (source)	Older people (70+)	Sc1	Sc2a/Sc2b	Sc3	Sc4	Comment
		MBCM	EXTENDED	WELFARE	LENGTHENED	
Accidents (DfT TAG 4.1/4.2)	Y	Y		Y	Y	DSI disaggregated by seniors and zone (not actual crashes), plus other disaggregation (Sc1). Welfare weights and lower discount rates apply (Sc3, Sc4).
Security (DfT TAG 4.1/4.2)	Y					Insufficient data and time to assess. No analysis undertaken.
Severance (DfT TAG 4.1/4.2)	Y					Insufficient data and time to assess. No analysis undertaken.
Accessibility (DfT TAG 4.1/4.2), including for spatially distributed activities	Y	Y				User benefits disaggregated by seniors and zone, plus other groups (Sc1). Note, Auckland has lower proportion of seniors to the New Zealand population.
Option values (DfT TAG 4.1/4.2)	Y					Insufficient data and time to assess. No analysis undertaken.

Source: Principal Economics

Note: DfT = Department for Transport; DSI = death and serious injury; MBCM = Waka Kotahi monetised benefits and costs manual; TAG = transport analysis guidance.

Table E.5 Issues identified in the literature relating to people with disabilities

Impact (source)	People with a disability	Sc1	Sc2a/Sc2b	Sc3	Sc4	Comment
		MBCM	EXTENDED	WELFARE	LENGTHENED	
Accidents (DfT TAG 4.1/4.2)	Y	Y		Y	Y	DSI disaggregated by disabled and zone (not actual crashes), plus other disaggregation (Sc1). Welfare weights and lower discount rates apply (Sc3, Sc4).
Security (DfT TAG 4.1/4.2)	Y					Insufficient data and time to assess. No analysis undertaken.
Severance (DfT TAG 4.1/4.2)	Y					Insufficient data and time to assess. No analysis undertaken.
Accessibility (DfT TAG 4.1/4.2), including for spatially distributed activities and physical access to transport system	Y	Y				User benefits disaggregated by disabled and zone, plus other groups (Sc1). Insufficient data for further analysis.
Option values (DfT TAG 4.1/4.2)	Y					Insufficient data and time to assess. No analysis undertaken.
Labour market deepening	Y	Maybe	Maybe			Potentially could consider modelled trips versus extra accessibility. Insufficient data and time to assess. No analysis undertaken.

Source: Principal Economics

Note: DfT = Department for Transport; DSI = death and serious injury; MBCM = Waka Kotahi monetised benefits and costs manual; TAG = transport analysis guidance.

Table E.6 Issues identified in the literature relating to households without access to a car

DfT TAG 4.1/4.2 and others	Households without access to a car	Sc1	Sc2a/Sc2b	Sc3	Sc4	Comment
		MBCM	EXTENDED	WELFARE	LENGTHENED	
Severance (DfT TAG 4.1/4.2)	Y					Insufficient data and time to assess. No analysis undertaken.
Accessibility (DfT TAG 4.1/4.2), including for spatially distributed	Y	Y				User benefits disaggregated by no-vehicle group and

DfT TAG 4.1/4.2 and others	Households without access to a car	Sc1	Sc2a/Sc2b	Sc3	Sc4	Comment
		MBCM	EXTENDED	WELFARE	LENGTHENED	
activities and physical access to transport system						zone, plus other groups (Sc1). Insufficient data for further analysis.
Option values (DfT TAG 4.1/4.2)	Y					Insufficient data and time to assess. No analysis undertaken.
Personal affordability (DfT TAG 4.1/4.2)	Y	Limited		Y		VOC and public transport fares disaggregated by no-vehicle group (and other groups) (Sc1).
Labour market deepening	Y	Maybe	Maybe			Potentially could consider modelled trips versus extra accessibility. Insufficient data and time to assess. No analysis undertaken.

Source: Principal Economics

Note: DfT = Department for Transport; MBCM = Waka Kotahi monetised benefits and costs manual; TAG = transport analysis guidance; VOC = vehicle operating costs.

Table E.7 Issues identified in the literature relating to households with dependant children

DfT TAG 4.1/4.2 and others	Households without access to a car	Sc1	Sc2a/Sc2b	Sc3	Sc4	Comment
		MBCM	EXTENDED	WELFARE	LENGTHENED	
As per children plus below						
Severance (DfT TAG 4.1/4.2)	Y					Insufficient data and time to assess. No analysis undertaken.
Labour market deepening	Y	Maybe	Maybe			Potentially could consider modelled trips versus extra accessibility. Insufficient data and time to assess. No analysis undertaken.
Transport reliability	Y	Limited				User benefits disaggregated by household with dependants and zone, plus other groups (Sc1).

Source: Principal Economics

Note: DfT = Department for Transport; MBCM = Waka Kotahi monetised benefits and costs manual; TAG = transport analysis guidance.

Table E.8 Issues identified in the literature relating to future generations

DfT TAG 4.1/4.2 and others	Children (<16)	Sc1	Sc2a/Sc2b	Sc3	Sc4	Comment
		MBCM	EXTENDED	WELFARE	LENGTHENED	
Soil and water pollution	Y					Insufficient data and time to assess. No analysis undertaken.
Greenhouse gases	Y	Y				User benefits disaggregated by no-vehicle group and zone, plus other groups (Sc1). Insufficient data for further analysis.
Other air pollution	Y					Insufficient data and time to assess. No analysis undertaken.
Residual project value	Y	Limited		Y		VOC and public transport fares disaggregated by no-vehicle group (and other groups) (Sc1),
Flora and fauna	Y	Maybe	Maybe			Potentially could consider modelled trips versus extra accessibility. Insufficient data and time to assess. No analysis undertaken.

Source: Principal Economics

Note: DfT = Department for Transport; MBCM = Waka Kotahi monetised benefits and costs manual; TAG = transport analysis guidance; VOC = vehicle operating costs.

Appendix F: List of macro strategic model outputs used

#	File name	#	File name
1	mf4606 AM Car HBW.csv	59	mf4692 ip Car Time.csv
2	mf4607 IP Car HBW.csv	60	mf4693 ip Car Distance.csv
3	mf4608 SP Car HBW.csv	61	mf4695 pm Car Time.csv
4	mf4609 PM Car HBW.csv	62	mf4696 pm Car Distance.csv
5	mf4610 OP Car HBW.csv	63	mf1971 am PT Journey Time.csv
6	mf4611 AM Car HBE.csv	64	mf1978 am PT Fare Matrix.csv
7	mf4612 IP Car HBE.csv	65	mf1979 ip PT Journey Time.csv
8	mf4613 SP Car HBE.csv	66	mf1986 ip PT Fare Matrix.csv
9	mf4614 PM Car HBE.csv	67	mf1987 pm PT Journey Time.csv
10	mf4615 OP Car HBE.csv	68	mf1994 pm PT Fare Matrix.csv
11	mf4700 am HBW Car GC.csv	69	mf4771 am PT Journey Time.csv
12	mf4701 ip HBW Car GC.csv	70	mf4778 am PT Fare Matrix.csv
13	mf4702 SP HBW Car GC.csv	71	mf4779 ip PT Journey Time.csv
14	mf4703 pm HBW Car GC.csv	72	mf4786 ip PT Fare Matrix.csv
15	mf4704 OP HBW Car GC.csv	73	mf4787 pm PT Journey Time.csv
16	mf1806 AM Car HBW.csv	74	mf4794 pm PT Fare Matrix.csv
17	mf1807 IP Car HBW.csv	75	mf1836 AM PT HBW.csv
18	mf1808 SP Car HBW.csv	76	mf1837 IP PT HBW.csv
19	mf1809 PM Car HBW.csv	77	mf1838 SP PT HBW.csv
20	mf1810 OP Car HBW.csv	78	mf1839 PM PT HBW.csv
21	mf1811 AM Car HBE.csv	79	mf1840 OP PT HBW.csv
22	mf1812 IP Car HBE.csv	80	mf1841 AM PT HBE.csv
23	mf1813 SP Car HBE.csv	81	mf1842 IP PT HBE.csv
24	mf1814 PM Car HBE.csv	82	mf1843 SP PT HBE.csv
25	mf1815 OP Car HBE.csv	83	mf1844 PM PT HBE.csv
26	mf1900 am HBW Car GC.csv	84	mf1845 OP PT HBE.csv
27	mf1901 ip HBW Car GC.csv	85	mf1915 am HBW PT GC.csv
28	mf1902 SP HBW Car GC.csv	86	mf1916 ip HBW PT GC.csv
29	mf1903 pm HBW Car GC.csv	87	mf1917 SP HBW PT GC.csv
30	mf1904 OP HBW Car GC.csv	88	mf1918 pm HBW PT GC.csv
31	mf1941 AM CarP HBW.csv	89	mf1919 op HBW PT GC.csv
32	mf1942 IP CarP HBW.csv	90	mf1920 am HBE PT GC.csv
33	mf1943 SP CarP HBW.csv	91	mf1921 ip HBE PT GC.csv
34	mf1944 PM CarP HBW.csv	92	mf1922 SP HBE PT GC.csv
35	mf1945 OP CarP HBW.csv	93	mf1923 pm HBE PT GC.csv
36	mf1946 AM CarP HBE.csv	94	mf1924 op HBE PT GC.csv

#	File name	#	File name
37	mf1947 IP CarP HBE.csv	**95**	mf4636 AM PT HBW.csv
38	mf1948 SP CarP HBE.csv	**96**	mf4637 IP PT HBW.csv
39	mf1949 PM CarP HBE.csv	**97**	mf4638 SP PT HBW.csv
40	mf1950 OP CarP HBE.csv	**98**	mf4639 PM PT HBW.csv
41	mf4741 AM CarP HBW.csv	**99**	mf4640 OP PT HBW.csv
42	mf4742 IP CarP HBW.csv	**100**	mf4641 AM PT HBE.csv
43	mf4743 SP CarP HBW.csv	**101**	mf4642 IP PT HBE.csv
44	mf4744 PM CarP HBW.csv	**102**	mf4643 SP PT HBE.csv
45	mf4745 OP CarP HBW.csv	**103**	mf4644 PM PT HBE.csv
46	mf4746 AM CarP HBE.csv	**104**	mf4645 OP PT HBE.csv
47	mf4747 IP CarP HBE.csv	**105**	mf4715 am HBW PT GC.csv
48	mf4748 SP CarP HBE.csv	**106**	mf4716 ip HBW PT GC.csv
49	mf4749 PM CarP HBE.csv	**107**	mf4717 SP HBW PT GC.csv
50	mf4750 OP CarP HBE.csv	**108**	mf4718 pm HBW PT GC.csv
51	mf1889 am Car Time.csv	**109**	mf4719 op HBW PT GC.csv
52	mf1890 am Car Distance.csv	**110**	mf4720 am HBE PT GC.csv
53	mf1892 ip Car Time.csv	**111**	mf4721 ip HBE PT GC.csv
54	mf1893 ip Car Distance.csv	**112**	mf4722 SP HBE PT GC.csv
55	mf1895 pm Car Time.csv	**113**	mf4723 pm HBE PT GC.csv
56	mf1896 pm Car Distance.csv	**114**	mf4724 op HBE PT GC.csv
57	mf4689 am Car Time.csv	**115**	ART3_3Zone.shp
58	mf4690 am Car Distance.csv	**116**	Population Forecast Scenario I11.6_SUMMARY_AllYears_200817.xlsx

Appendix G: Composite vehicle operating costs

We determine a composite vehicle operating cost by assuming a zero gradient for all roads, and taking the sum product of vehicle operating costs for different vehicle classes and the average composition of vehicle classes on urban arterial roads at all times.

Table G.1 Estimated composite vehicle operating costs

Composite vehicle operating cost (VOC)						
Speed (km/h)	Passenger car	LCV	MCV	HCVI	HCVII	Estimated composite VOC (cents per km)
10	34.0	44.2	68.1	118.9	172.9	**39.3**
15	30.4	39.2	63.2	111.5	173.1	**35.6**
20	27.7	35.5	59.7	105.4	169.5	**32.7**
25	25.8	32.9	57.2	100.8	166.0	**30.7**
30	24.4	30.9	55.6	97.5	163.2	**29.2**
35	23.4	29.6	54.6	95.3	161.3	**28.1**
40	22.7	28.6	54.1	94.0	160.1	**27.4**
45	22.2	28.0	53.9	93.2	159.7	**26.9**
50	21.8	27.6	54.0	93.0	159.8	**26.5**
55	21.7	27.5	54.4	93.2	160.5	**26.4**
60	21.6	27.5	54.9	93.8	161.5	**26.4**
65	21.6	27.7	55.5	94.7	163.0	**26.4**
70	21.7	28.0	56.3	95.8	164.7	**26.6**
75	21.9	28.3	57.2	97.1	166.8	**26.9**
80	22.1	28.8	58.2	98.6	169.0	**27.2**
85	22.4	29.3	59.3	100.2	171.5	**27.6**
90	22.7	29.9	60.4	102.0	174.1	**28.0**
95	23.0	30.5	61.6	103.8	176.9	**28.4**
100	23.4	31.2	62.8	105.8	179.8	**28.9**
105	23.8	31.9	64.0	107.8	182.8	**29.4**
110	24.2	32.7	65.3	109.9	186.0	**30.0**
115	24.7	33.5	66.6	112.1	189.2	**30.6**
120	25.1	34.3	67.9	114.3	192.5	**31.1**

Source: Principal Economics, adapted from Waka Kotahi (2021b, p. 338)

Note: LCV = light commercial vehicle; MCV = medium commercial vehicle; HCVI = heavy commercial vehicle I; HCVII = heavy commercial vehicle II.

Table G.2 Estimated traffic composition for urban arterial roads at all periods

Traffic composition for urban arterial roads at all periods					
Vehicle class	**Passenger car**	**LCV**	**MCV**	**HCVI**	**HCVII**
Traffic composition %	85%	10%	2%	1%	2%

Source: Adapted from Waka Kotahi (2021b, p. 303)

Note: LCV = light commercial vehicle; MCV = medium commercial vehicle; HCVI = heavy commercial vehicle I; HCVII = heavy commercial vehicle II.

Appendix H: Abbreviations

Abbreviation	Description
AADT	Annual average daily traffic
AHP	Analytical Hierarchy Process
AM	AM peak
ATAP	Auckland Transport Alignment Project
BBC	Better Business Case
BCR	Benefit–cost ratio
CBA	Cost–benefit analysis
CO_2	Carbon dioxide
DfT	Department for Transport
DSI	Death and serious injury
GDP	Gross domestic product
GIS	Geographic information system
GPS	Government Policy Statement
HBE	Home-based education
HBW	Home-based work
HDV	Heavy duty vehicles
HGV	Heavy goods vehicle
HM	Her Majesty
IP	Interpeak
ITF	International Transport Forum
LDEV	Mean log deviation
LGBTQI+	Lesbian, gay, bisexual, transgender, queer, intersex, asexual, or other sexuality and gender diverse identities
LSF	Living Standards Framework
MBCM	Waka Kotahi Monetised benefits and costs manual
MCA	Multi-criteria analysis
MCDA	Multiple-criteria decision analysis
MSM	Macro strategic model
NMBM	Waka Kotahi non-monetised benefit and cost manual
NPS-UD	National Policy Statement on Urban Development
NPV	Net present value
NZDEP	New Zealand Deprivation Index
NZIER	New Zealand Institute of Economic Research
NZIMD	New Zealand Index of Multiple Deprivation
OECD	Organisation for Economic Co-operation and Development
OP	Off peak
PM	PM peak

RLTP	Regional Land Transport Plan
SA1	Statistical Area 1
SA2	Statistical Area 2
SIA	Social impact assessment
SP	School peak
TAG	Transport analysis guidance
UK	United Kingdom
US	United States of America
VOC	Vehicle operating costs
VOSL	Value of a statistical life
WEI	Wider economic impact
WTA	Willingness to accept
WTP	Willingness to pay