A narrative literature review of the effectiveness of interventions to reduce light vehicle travel

March 2023

E Pacheco, WSP Research & Innovation, Wellington
V Ivory, WSP Research & Innovation

Waka Kotahi NZ Transport Agency research report 707
Contracted research organisation – WSP Research & Innovation

WAKA KOTAHI NZ TRANSPORT AGENCY
New Zealand Government

ISBN 978-1-99-106810-1 (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

Pacheco, E., & Ivory, V. (2023). *A narrative literature review of the effectiveness of interventions to reduce light vehicle travel* (Waka Kotahi NZ Transport Agency research report 707).

WSP Research & Innovation was contracted by Waka Kotahi NZ Transport Agency in 2022 to carry out this research.

Keywords: car use reduction, driving reduction, light vehicle travel, mobility management, mode shift, road traffic reduction, transport intervention, travel behaviour, vehicle kilometres travelled

An important note for the reader

Waka Kotahi NZ Transport Agency is a Crown entity established under the Land Transport Management Act 2003. The objective of Waka Kotahi is to undertake its functions in a way that contributes to an efficient, effective and safe land transport system in the public interest. Each year, Waka Kotahi funds innovative and relevant research that contributes to this objective.

The views expressed in research reports are the outcomes of the independent research and should not be regarded as being the opinion or responsibility of Waka Kotahi. The material contained in the reports should not be construed in any way as policy adopted by Waka Kotahi or indeed any agency of the New Zealand Government. The reports may, however, be used by New Zealand Government agencies as a reference in the development of policy.

While research reports are believed to be correct at the time of their preparation, Waka Kotahi and agents involved in their preparation and publication do not accept any liability for use of the research. People using the research, whether directly or indirectly, should apply and rely on their own skill and judgement. They should not rely on the contents of the research reports in isolation from other sources of advice and information. If necessary, they should seek appropriate legal or other expert advice.

Acknowledgements

The authors would like to thank the steering group for the support and feedback provided through the different stages of this project. We acknowledge the contribution of the following people in no particular order:

- Sandy Fong, Principal Research Advisor, Waka Kotahi – Research Owner and Chair
- Whitney Adam, Senior Policy Advisor, Placemaking and Urban Development, Te Manatū Waka Ministry of Transport
- Mieke Welvaert, Senior Economist, Domain Strategy, Economics and Evaluation, Te Manatū Waka Ministry of Transport
- Kathryn King, Manager Urban Mobility, Multimodal Innovation, Transport Services, Waka Kotahi
- Colin Morrison, Principal Advisor, Environment & Sustainability, Haumaru Taiao Safety, Health & Environment, Waka Kotahi
- David Darwin, Lead Investment Planning Advisor, Policy and System Planning, Transport Services, Waka Kotahi

Abbreviations and acronyms

ACTIVE	Activating Communities to Improve Vitality and Equality
GHG	greenhouse gas
IPEN	International Physical Activity and Environment Network
LVT	light vehicle travel
PnR	park and ride
SA1	statistical area 1
SA2	statistical area 2
VKT	vehicle kilometres travelled
WFH	working from home
WPL	Workplace Parking Levy (Nottingham)

Contents

Executive summary

The context

The transport sector is one of New Zealand's largest sources of greenhouse gas emissions. It is responsible for 17% of gross domestic emissions, and 39% of total domestic CO_2 emissions. It is in this context that reducing light vehicle travel (LVT) is one of the targets of Aotearoa New Zealand's first emissions reduction plan, which outlines the emissions reduction actions needed across sectors in the next 15 years. However, to reduce LVT and make (and implement) the best-informed choices, decision-makers and policy analysts need updated evidence of effective interventions as well as an analysis of their relevance and applicability to New Zealand.

This report is based on a narrative review of available literature regarding effective interventions to reduce LVT. It assessed the relevance of identified interventions to New Zealand Tier 1 and 2 urban environments.[1] The review also looked at the necessary and sufficient conditions for sustained reduction of LVT in the country.

Our approach

Our approach for this narrative literature review involved calling on relevant recent collections, including those collated by Waka Kotahi NZ Transport Agency and made available to this project as well as literature collated as part of complementary current and recent reviews commissioned to WSP New Zealand Ltd. This was complemented with searches in research databases using a combination of keywords.

In addition, references in selected papers were also tracked down, retrieved and assessed for inclusion and quality. The interventions identified and analysed have also been used for an online map-based database and dashboard; these can be used as resources for accessing effective interventions to reduce LVT.

What we found

Our literature review identified 24 relevant studies looking at effective interventions for reducing LVT. These were grouped into six categories:

- incentives
- information and advice
- congestion charging
- infrastructure development and improvements
- car parking
- other interventions.

The identified studies come from multiple regions, with most of them being conducted in Western Europe. They are based on different research approaches, from randomised controlled trials to cohort studies and modelling. They also differ on the types and/or combinations of data used, the analytical lenses applied, and the extent and context of the interventions reported and evaluated. Outcome measures varied considerably across the studies, which limited comparability.

[1] The National Policy Statement on Urban Development categorises New Zealand's urban environments into three tiers based on population size and growth rates. Tier 1 includes Auckland, Tauranga, Hamilton, Wellington, and Christchurch. Tier 2 includes Whangārei, Rotorua, New Plymouth, Napier Hastings, Palmerston North, Nelson Tasman, Queenstown, and Dunedin.

Of note, the limited number of relevant studies identified shows that there is a paucity of evidence as well as a gap between the development of a knowledge base and its application.

Our recommendations and lessons

From the findings of the narrative literature review, we have developed a set of recommendations grouped in three main categories:

- how evidence is collated and evaluated
- how evidence is generated
- further development of the LVT reduction evidence base.

How evidence is collated and evaluated

- Develop a mosaic of evidence that represents the diverse methods required to evaluate the full range of LVT reduction interventions in New Zealand. This approach needs to incorporate useful, structured methods for classifying and comparing various interventions (and purposes) and evaluation types, including factors such as context as well as the internal validity and quality of study design.
- Shift the focus of undertaking and comparing intervention evaluations from hypothesis testing to assessing the functions of an intervention.
- When comparing interventions, consider the purpose: Is the aim for a lot of change for few, or a little change for many?
- Beware of 'effect size' comparisons: Interventions addressing determinants will have smaller effect sizes than targeted interventions but have a greater reach across populations, and therefore impact.
- Interventions that seek to address determinants of behaviour (eg, LVT and mode shift) may be best evaluated by considering the findings from multiple studies to come to a 'good enough' conclusion.

How evidence is generated

- Fund and publish evaluations through integration into transport project planning scope and budgets.
- Allow for evaluation data gathering to take place at appropriate time scales (ie, before an intervention starts and after behaviours have adapted to changes).
- Aim for comparability in the measurement and reporting of project evaluations. Comparability and causation are the goals of quality methods and reporting.
- Optimise opportunities arising from real-world natural trials and experiments through staging and comparisons with non-intervention sites.
- Facilitate long-term, evolving evaluations of complex changes likely to affect LVT and mode shift (eg, 20-minute city endeavours).
- Capture information on the context of an intervention to aid comparisons, including geographical, environmental, economic, socio-cultural and built environment features.
- Recognise that the academic research model can add value to the wider evidence base and support collaborations between researchers and the transport sector (perhaps treating the Te Ara Mura research programme as a case study for identifying lessons).

Further development of the LVT reduction evidence base

- Explore how to integrate intervention evaluations with causal modelling-based assessments.
- Combine and synthesise evidence and intervention types – towards building a mosaic of evidence.
- Explore how the intervention types identified in this study might synergistically interact with each other and the specific context of Tier 1 and 2 urban environments in New Zealand.

- User-test the interactive dashboard to identify the most useful filters and information, including how contextual information could be added through spatially available information.
- Explore how the evidence needs of different users could be met in a mosaic-type evidence base. For example, how could the diversity of evidence be made helpful (rather than a hindrance) in the Environment Court as well as for community engagement?
- The relevance to urban environment ranking in this report was dichotomised as 'yes' or 'no'. A more nuanced ranking could be reached through more in-depth consideration of city characteristics and the relative maturity of non-vehicle transport cultures and infrastructure.

We believe that Waka Kotahi as well as key stakeholders in the transport space (including the research community) and the general public will find this literature review useful. The insights it provides can contribute to the ongoing conversation about how to effectively reduce LVT, and to inform the development of policies and interventions aimed to meet the key goals of the government's emissions reduction plan.

Abstract

The transport sector is one of the largest sources of greenhouse gas emissions in New Zealand. To address this issue, the government is planning a set of actions to be implemented in the next 15 years. One of these actions deals with transport emissions and targets for a reduction in light vehicle travel. However, to achieve this goal, there is a need for both an updated assessment of effective interventions and an analysis of their relevance and applicability to the New Zealand context. This report seeks to close the gap by conducting a narrative literature review of a collection of existing literature, supplemented with some targeted searches. With the focus on evidence relevant to New Zealand's largest and fastest growing urban environments, the report identified 24 publicly available research outputs from around the world (mainly from Western European countries). The papers assessed differ not only in the type of research method and analysis applied but also the form of intervention(s) evaluated, the duration of the intervention and follow-up periods, the characteristics of the population groups or intervention sites studied, the measures, results and metrics relevant to New Zealand, and the outcomes of the interventions. Although these differences may represent a challenge in terms of comparability and transferability, they also provide opportunities and lessons for policy- and decision-makers. Finally, the report discusses the implications of the review and its findings and provides some directions and recommendations for future research, policy and practice for the measurement and evaluation of interventions.

1 Introduction

1.1 Overview

Aotearoa New Zealand's first emissions reduction plan was recently released by the government (Ministry for the Environment, 2022). The plan sets the direction for climate action for the next 15 years and outlines the actions that need to be taken across sectors of the economy to reduce emissions. The document states that transport is one of the largest sources of greenhouse gas (GHG) emissions in New Zealand. It is responsible for 17% of gross domestic emissions and 39% of total domestic CO_2 emissions (Ministry for the Environment, 2022). A light vehicle travel (LVT) reduction target is proposed in the plan as a key mechanism for reducing transport emissions. The proposed target is expected to apply to the largest New Zealand cities and will require a rapid yet equitable reduction of current vehicle use.

Currently, Arataki – Waka Kotahi NZ Transport Agency's long-term view of what is needed to deliver on the government's current priorities and longstanding outcomes for the land transport system – has identified broad types of interventions to meet strategic transport goals and outcomes. In this respect, Thorwaldson et al. (2021) provided a preliminary scan of evidence evaluating the GHG emission reduction benefits from land transport mode shift programmes and projects. The recent Intergovernmental Panel on Climate Change (2022) report recommends creating human-centred urban areas with a focus on sustainable transport modes. However, Waka Kotahi still needs to build improved evidence on which interventions offer the best opportunity to reduce non-freight, private LVT within the wider framework of emissions reduction and co-benefits.

Within the Waka Kotahi Avoid–Shift–Improve GHG emissions reduction model, interventions to reduce LVT could help avoid and reduce private vehicle trips by improving accessibility from integrated land use, as well as shifting travel to low-emission modes (eg, active and public transport) (Waka Kotahi, 2020). Without understanding the effectiveness of interventions, it is difficult to know if they are impactful (in the intended way), implementable, and represent good value for money.[2] There is also a risk of wasted effort if interventions to reduce LVT:

- are applied without reference to solid and reliable evidence of effectiveness
- are applied without the necessary and sufficient conditions for success, including integration and phasing with other interventions that will allow interventions to be packaged together
- have adverse impacts on equity.

1.2 Purpose and objectives

The purpose of this project undertaken by WSP was to conduct a narrative review of available literature regarding effective interventions to reduce LVT and assess its relevance to New Zealand Tier 1 and 2 urban environments.[3] The review includes the necessary and sufficient conditions required for sustained LVT reduction so that appropriate interventions can be selected for different contexts. In doing so, the evidence

[2] Examples of reviews designed for making evidence on interventions transferable and applicable to differing contexts are the International Transport Forum's Transport Climate Action Directory and the earlier KonSULT.

[3] The National Policy Statement on Urban Development categorises New Zealand's urban environments into three tiers based on population size and growth rates. Tier 1 includes Auckland, Tauranga, Hamilton, Wellington, and Christchurch. Tier 2 includes Whangārei, Rotorua, New Plymouth, Napier Hastings, Palmerston North, Nelson Tasman, Queenstown, and Dunedin.

gathered and analysed provides the basis for a database that can be used as a resource for accessing effective interventions to reduce LVT.

WSP's research objectives are to:

- review domestic literature and international literature relevant to New Zealand on interventions to reduce LVT
- undertake an analysis of the literature to identify the necessary and sufficient conditions for sustained LVT reduction in local contexts
- characterise interventions for their relevance to New Zealand Tier 1 and 2 urban environments
- develop a database as a resource for determining standard vehicle kilometres travelled (VKT) reduction interventions in New Zealand.

The scope of this study includes:

- a narrative review and analysis of literature relevant to New Zealand on the effectiveness of interventions to reduce LVT[4]
- documenting the necessary and sufficient conditions that influence the effectiveness of VKT reduction of each intervention, including any interdependencies
- documenting the key metrics to adjust the effectiveness of each intervention according to the varying local context and application, which may include:
  - statistical information such as effect size and confidence intervals
  - applicability to spatial areas, land area types, or as combinations of statistical areas 1 and 2 (SA1 and SA2) if applicable[5]
  - effectiveness measured in comparable units of mode shift, VKT reduction, GHG emissions, etc
  - any relevant transport journey/demographic factors
  - any other relevant metrics identified
- any material secondary impacts (with reference to the Transport Outcomes Framework) arising from the interventions.

1.3 Outside of scope

The following are considered as being out of scope for this project:

- VKT reduction interventions where LVT is not the primary focus
- mode shift interventions where LVT reduction is identified as a benefit but not otherwise assessed (eg, where the primary impact is safety)
- mode shift activities where changes have not been formally evaluated and reported
- reports of trends in LVT/VKT without assessment of the impact of specific interventions or measures (eg, where change is attributed to pandemic conditions).

[4] The review is primarily based on existing collations from Waka Kotahi and Te Manatū Waka, and literature reviews from related research projects.

[5] SA1 and SA2 are Stats NZ's most detailed non-administrative geographical classifications for published outputs (see https://www.stats.govt.nz/information-releases/statistical-area-1-dataset-for-2018-census-updated-march-2020#footnotes).

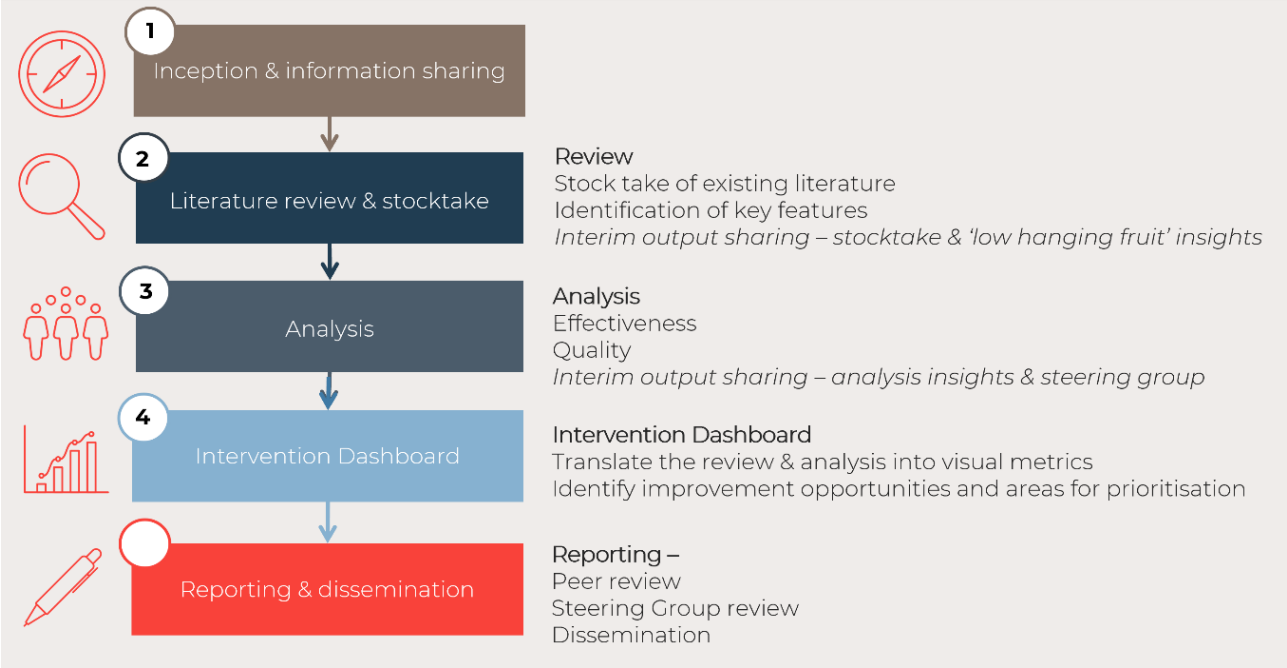
1.4 Research approach

The research approach guiding this project involved five stages:

1. inception and information sharing
2. literature review and stocktake
3. analysis
4. intervention dashboard
5. reporting and dissemination.

The steps undertaken for each of these stages are outlined below in Figure 1.1.

Figure 1.1 Outline of WSP's five-stage research approach



2 Methodology

The research approach guiding this project was a narrative literature review and analysis. Narrative reviews are used to describe and summarise literature and are useful when addressing non-specific topics (Baethge et al., 2019) and can follow a systematic approach to the searching and screening of literature, data extraction and analysis, and presentation of the review (Paré & Kitsiou, 2017). This project sought to review literature on the effectiveness of a non-specific range of interventions to reduce LVT, consider their relevance to New Zealand Tier 1 and 2 urban environments and, based on this evidence, create a database that can be used as a resource for selecting the most effective interventions to reduce LVT. The specific research questions that have guided this project were:

- What interventions can deliver reductions in LVT? How do they work?
- What are the necessary and sufficient conditions for effective interventions?
- What are the features of interventions that can be generalised to:
  - New Zealand's Tier 1 and 2 urban environments
  - key population groups and communities?
- What types of interventions can bring about sustained reductions in LVT?

2.1 Search criteria and data extraction

To answer these questions, we applied a systematic approach to search, retrieve, analyse and evaluate academic and grey literature about LVT reduction interventions. Because project timelines did not allow for an exhaustive systematic review methodology, a pragmatic approach was taken to search for literature. The search started with calling on relevant recent collections, including those collated by Waka Kotahi and made available to this project. We were also able to call on the following literature collated as part of complementary current and recent reviews commissioned to WSP.

- *Latent demand for walking & cycling* (Waka Kotahi) (2020)
- *Safety interventions and their contribution to mode shift* (Waka Kotahi) (current)
- *How to positively incentivise safe driving choices* (Waka Kotahi) (current)
- *Reducing GHG emissions in urban form* (BRANZ) (current)
- *Let's Get Wellington Moving (LGWM) travel behaviour change (TBC) critical review* (2021)

Where gaps emerged in certain types of interventions (eg, gamification), the above literature was supplemented through searches in research databases such as ScienceDirect and Google Scholar and a combination of keywords for our search (eg, 'car use reduction', 'driving reduction', 'transport intervention', 'intervention'). Our initial focus was on post-2012 papers and reports, due to significant shifts in transport. However, as available evidence was shown to be limited from that period, we extended the time range of our search based on the quality criteria outlined below in section 2.2. In addition, references in selected papers were also tracked down, retrieved, and assessed for inclusion and quality.

2.2 Inclusion criteria and quality assessment

A key aspect of our approach was that the literature reviewed contained details about the effectiveness of an intervention for achieving LVT reduction, and for contextual factors that can inform generalisability to local settings and the conditions needed for success. The goal was to include details such as:

- statistical information such as effect size and confidence intervals

- applicability to spatial areas, land area types, or as combinations of SA1 and SA2 if applicable
- effectiveness measured in comparable units of mode shift, VKT reduction, GHG emissions, etc
- any relevant transport journey/demographic factors, including specificity to population groups, types of travel, urban form features
- any other relevant metrics identified.

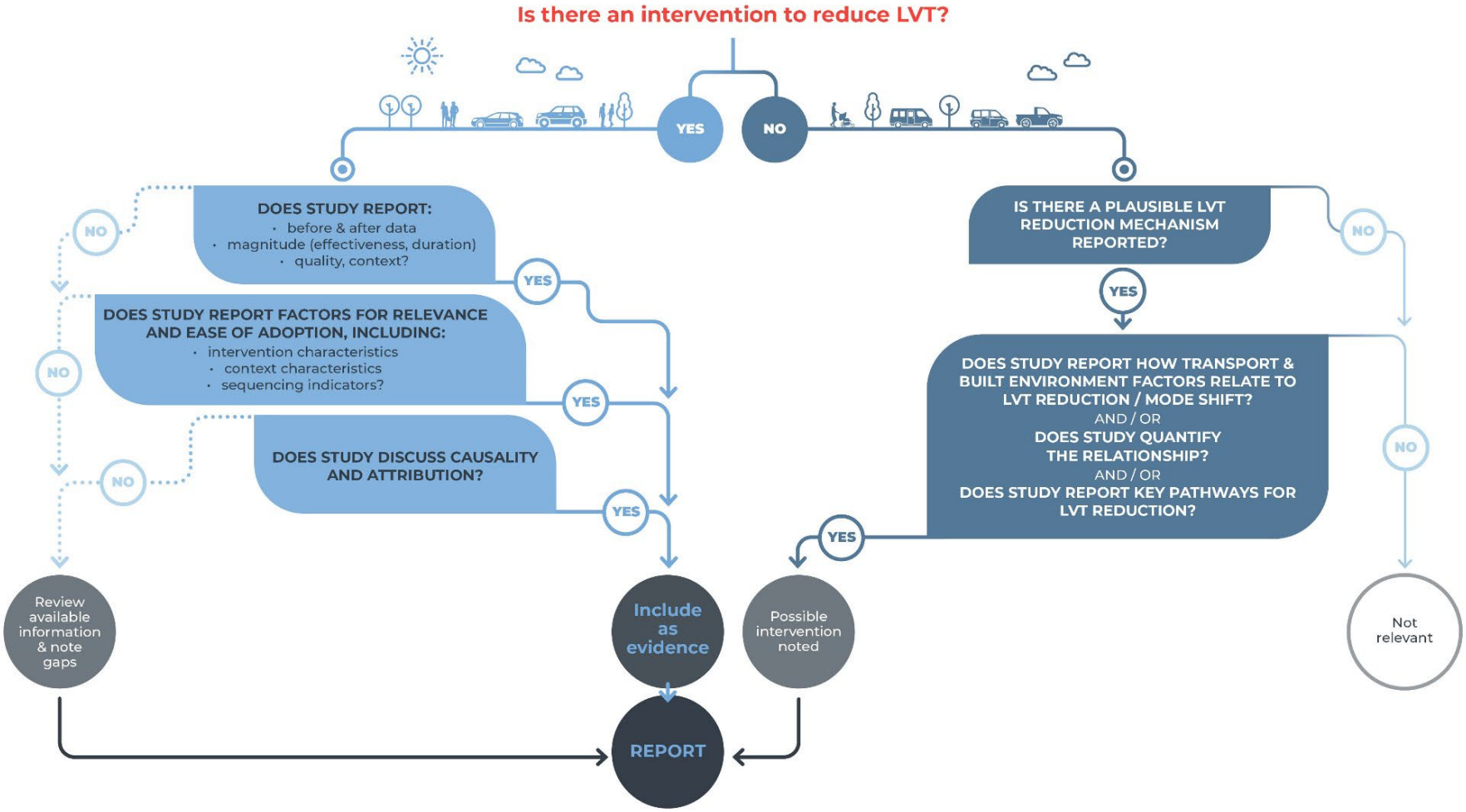
The initial output of the literature review was a stocktake of interventions looking at reducing light vehicle VKT. The stocktake was recorded and organised in spreadsheet form so that it can be transferred later into the interactive dashboard. The spreadsheet contained the following sections:

1. Study details (ie, year of publication, author's name, name of publication, study country, modes evaluated).
2. Intervention details (ie, location of intervention, intervention scale, intervention type and purpose, summary of intervention, research method, context and conditions).
3. Effectiveness in terms of traffic reduction (ie, reduction measures, results, and outcomes) and/or mode shift and/or active/public transport behaviour changes.
4. Intervention type lever, which included interventions such as parking policy, public transport services and infrastructure improvement, among others.
5. Additional information (ie, intervention impact, funding mechanism, partnership structure, barriers/constraints/limitations, factors attributed to behaviour change, applicability to the New Zealand context).

2.3 Decision-tree research framework for intervention assessment

Our approach to the literature review recognised several challenges. Firstly, achieving reductions in LVT is complex and necessarily involves addressing multiple drivers. Secondly, LVT reduction could occur explicitly through avoiding and reducing travel, and/or implicitly through shifting modes (however, we do not assume substitution of modes will be 100%). We therefore sought a wide range of interventions, outcomes, and types of evidence to gain the most useful coverage of interventions. The development of the stocktake of interventions was informed by a decision-tree framework that guided not only our search but also inclusion criteria (see Figure 2.1 below). The left-hand side of the decision tree focuses on intervention reports showing effective results and outcomes for reducing LVT through explicit or implicit means. Rather than excluding studies where reports did not provide complete information (eg, not providing a description of the intervention context to allow assessment of relevance and ease of adoption), pertinent information was gleaned from the study to be reported in the review and gaps noted. The right-hand side deals with other research outputs that do not meet our criteria but still hold relevant insights or discuss evidence gaps.

Figure 2.1 Literature review decision-tree framework for intervention search and inclusion



2.4 'Significance for New Zealand' of existing evidence

While the original intent of the project was to be able to compare and analyse interventions to identify the most appropriate interventions for reducing LVT in New Zealand, two things quickly became apparent. Firstly, the type of interventions relevant to LVT reduction are many and varied; secondly, what is reported is equally variable. This meant that relevant information was frequently not available to compare and contrast interventions, nor to assess them in terms of relatively granular criteria. For example, regarding the necessary and sufficient conditions for success in local contexts, information on spatial scales was often absent or not relevant (eg, if the intervention was targeted at individuals or households). It also meant that determining what was a more or less 'effective' intervention was impractical. Instead, in consultation with Waka Kotahi, a more pragmatic approach was taken that recognised the diversity of the interventions reviewed and the limitations of evaluation and reporting methods.

Information was extracted to be able to compare interventions by their:

- type
- purpose
- results and mode shift related outcomes
- contextual factors
- relevance and transferability to New Zealand and particularly to Tier 1 and 2 urban environments.

Information on the context and methods of the interventions was extracted to allow analysis for the significance of interventions to New Zealand. Contextual details extracted included factors such as the level of urbanicity, socio-demographic characteristics of the intervention target population, and maturity of the active and public transport infrastructure and culture. Over the course of the review, the authors engaged in an iterative analytical process to make sense of and evaluate the characteristics of the interventions and implications of the evidence for New Zealand. This process started from the beginning of the project when the stocktake of interventions started being recorded in a spreadsheet format and continued with periodical meetings as new evidence was added to the spreadsheet.

We developed a rating system that included two domains. The first domain looked at the relevance of the interventions for Tier 1 and 2 urban environments. For each tier we applied a two-option scale (Yes or No) acknowledging that an intervention could be relevant for any of the two tiers or both. The second domain assessed was transferability. In this respect, we employed a four-level scale with each item in the scale being also represented with one to four stars. The four items utilised for assessing the transferability of the interventions to the New Zealand context were:

- ☆☆☆☆ – Method immediately transferable
- ☆☆☆ – Method needs adaptation
- ☆☆ – Method needs local infrastructure upgrades
- ☆ – Method needs major upgrades.

The extracted intervention and contextual qualities were correlated with researchers' local knowledge of the urban form and transport characteristics of Tier 1 and 2 urban environments to determine the relevance and transferability rating for each intervention.

3 Results

Our search strategy identified 24 relevant studies looking at effective interventions in terms of reducing LVT. While most of the studies reviewed were conducted in Europe, we also identified relevant interventions carried out in Canada, the United States, Australia and New Zealand. Different types of research approaches were applied to assess the effect of the interventions, with randomised controlled trials and cohort studies being the most common. Regarding intervention types, we found that they also varied across studies. The most common were new/extended infrastructure, incentives, and congestion charging. They were followed by interventions based on information and advice, car parking, gamification, and other. However, while some studies focused on one particular type of intervention (primary intervention), others also included secondary linked interventions. The 24 papers reviewed are grouped by intervention type below. They are immediately summarised in table format following the narrative description of each intervention. In addition to the information highlighted above, each table includes:

- Avoid/Reduce, Shift, or Improve categorisation of primary interventions
- key results
- outcomes related to mode shift
- context and conditions
- an assessment of the relevance and transferability to New Zealand based on the rating scales described in section 2.4.

3.1 Incentives (extrinsic and intrinsic)

An incentive, as defined in complementary work conducted by WSP, involves ‘a range of actions, systems, and/or approaches (sometimes applied in conjunction) to promote and/or encourage desired behaviour’ (Thomas et al., 2022, p. 7). There are two types of incentives: extrinsic and intrinsic. Extrinsic incentives are financial or can easily be assigned a financial value (like an insurance discount, prizes, or other material goods). Intrinsic incentives are intangible and cannot easily be given a financial value (like reputational or recognition-based feedback by parents, peers, a colleague, or technology) (Thomas et al., 2022).

We identified five articles on incentives that reported some level of effect on reducing LVT either through avoiding or reducing trips or shifting modes. Three of these interventions took place in the Netherlands, one in Germany, and one in Japan. All the papers deal with the impact of extrinsic incentives (financial/material incentives). However, the extent and duration of the incentives applied differed between studies. Overall, while extrinsic incentives seem to have a positive impact, the evidence does not provide details of what happens with mode-shift behaviours after the incentives ended. In addition, for incentives to work, other conditions were needed such as providing extended public transport services or information resources. From the limited number of studies in our collection, it appears that the use of incentive-based interventions dates back from early 2000s. Finally, an existing gap in the literature is that the role of intrinsic incentives for reducing LVT remains unknown.

For example, Ben-Elia and Ettema (2011) assessed the effect of two types of incentives to reduce car use during rush hours (between 7:30 and 9:30 am) in The Hague. The intervention consisted in providing either money or a mobile phone to a group of 341 participants if they avoided travelling by car on a busy motorway during the morning rush-hour. These participants were previously identified via licence plate observations as regular car commuters with three trips per week or more. The study found that, overall, about 50% of participant who received any of the two incentives changed their driving times while 15% changed to the use of public transport. The study also found that changes were more significant among those who received the financial reward compared to those who chose the mobile device (the latter were more likely to choose to

drive later). In terms of gender, overall, males tended to change behaviour more often than women. Meanwhile, child chauffeuring or childcare appear to constrain change of behaviour. The study also found that socio-economic characteristics, work-time flexibility, attitudes to commuting alternatives, the availability of travel information, and even weather conditions also play a role (Ben-Elia & Ettema, 2011). See Table 3.1 for a summary of this intervention.

Table 3.1 Summary of research output by Ben-Elia and Ettema (2011)

Name of study	*Rewarding rush-hour avoidance: A study of commuters' travel behaviour*
Author	Ben-Elia & Ettema, 2011
Country	The Netherlands
Purpose	Avoid/Reduce & Shift: To reduce car-based commuting during rush hours in a busy motorway in The Hague.
Intervention type	Primary intervention: Financial and material incentive (money or a smartphone) run for 13 weeks.
Method	Web-based pre- and post-test surveys, data from detection equipment and electronic vehicle identification as well as backup road-side cameras installed in road of intervention.
Evidence type	Cohort study. Other factors also having an impact: socio-economic characteristics, work-time flexibility, attitudes to commuting alternatives, the availability of travel information, and weather conditions.
Result	About half reported changing their driving times; 15% changed to public transport.
Mode shift related outcome	Decreased vehicle trips, increased public transport trips.
Context of the study	Urban area. Most participants were highly educated and had moderate-to-high income. All participants were frequent car commuters from the town of Zoetermeer and the vast majority were working at the time in The Hague or its surroundings. No further information was provided regarding public transport services available to support intended mode shift.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes if there is congestion.
Transferability to New Zealand	☆☆☆ – Requires there to be viable alternative travel options.
Design notes for New Zealand	Needs adaptation to appropriate financial incentives for target audience.

In another study conducted in the Netherlands (see de Kruijf et al., 2018), financial incentives were also applied to encourage mode shift from car use to e-bikes. A total of 547 participants from the province of North Brabant took part in the study. To stimulate the use of e-bikes instead of cars, these participants received a monetary reward depending on their e-bike use while commuting. The incentive consisted of €0.15 per kilometre during the peak hours and €0.08 per kilometre in the off-peak hours. Participants could earn a maximum of €1,000 per person overall based on the number of kilometres cycled multiplied by the incentive. Data was collected via three surveys administered before and after the intervention. Additionally, data about e-bike use was gathered through a smartphone app that tracked e-cycling behaviour. The study found that vehicle trips decreased while cycling trips jumped. In this respect, after one month, e-bike commute trips increased from 0% to 68%, with an increase up to 73% after six months. However, the study also found that distance is an important factor – e-bike use decreased as commuting distance increased. Other factors that influenced e-cycling were age, gender, physical condition, car ownership and household composition (de Kruijf et al., 2018). A summary of this research output is presented in Table 3.2.

Table 3.2 Summary of research output by de Kruijf et al. (2018)

Name of study	*Evaluation of an incentive program to stimulate the shift from car commuting to e-cycling in the Netherlands*
Author	de Kruijf et al., 2018
Country	The Netherlands
Purpose	Shift: Increase non-car modes/active travel (e-bikes) in the province of North Brabant.
Intervention type	Primary intervention: Financial incentive to stimulate switch to e-bikes from cars. Study ran for six months in 2013.
Method	Three surveys and e-bike data from a smartphone app that tracked e-cycling behaviour.
Evidence type	Cohort study.
Result	After one month, e-bike commute trips increased from 0% to 68%, with an increase up to 73% after six months.
Mode shift related outcome	Decreased vehicle trips, increased cycling trips.
Context of the study	Province (no city specified). Half of participants were over 50 years old. Nearly 70% reported to have a good/excellent physical condition. Initiative shows potential when targeting car-only commuters. No attention was given to existing road safety and cycling infrastructure or topographical characteristics.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes.
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable but will need some level of cycling infrastructure.
Design notes for New Zealand	Target populations based on cyclable catchments to central business district or major destinations. Impact likely to be enhanced with improvements to infrastructure. Poor experiences could entrench car dependency.

Another study evaluated the use of a different type of material incentive, namely a free travel pass, to prevent car traffic and congestion in Utrecht, The Netherlands (Stumpel-Vos et al., 2013). In 2008 the Municipality of Utrecht, along with other key agencies and organisations, coordinated and implemented a mobility plan that aimed at raising private companies' awareness on urban mobility, reducing the number of cars on the roads in Utrecht during peak hours, and increasing the use of alternative transport modes by implementing the 'UB pass', a free public transport pass (see Figure 3.1). UB-pass holders were able to use the buses, trams and rental bikes in the region. The initiative was implemented to reduce traffic disruption during the major road works planned in and around Utrecht. A marketing communication plan was implemented in parallel and lasted from late 2008 to February 2010. In July 2009 a baseline survey was completed by 1,392 UB-pass owners (partly by email and partly by letter). A second online survey was conducted in February 2010 among UB-pass owners. The total sample for the second survey was 1,890. Furthermore, all new pass owners during 2010 were asked to fill in an online questionnaire; 2,551 participants filled in the questionnaire completely. The study found a decrease in car use and calculated a total reduction of 2,880 car trips in the morning rush hours from 6 am to 10 am per working day. A large majority of the UB-pass owners (95%) used the pass to travel to work, with 61% of respondents who travel to work three days a week using the pass those three days. Meanwhile, 51% of those who travel to work four days a week used the pass those four days, and 52% of participants who travel to work five days a week used the pass those five days. Furthermore, 40% of UB-pass owners used to drive a car or motorcycle to travel to work before having the UB pass. Of this percentage, 37% said they will keep using public transport

rather than returning to driving their cars once the major road works are completed. While the intervention showed positive results, an important condition to consider is the complementary services provided to commuters such as private shuttle buses from local companies to park and ride (PnR) stations as well as train stations (Stumpel-Vos et al., 2013). See Table 3.3 for a summary of the study.

Figure 3.1 Example of the UB pass (reprinted from Stumpel-Vos et al., 2013, p. 6)

Table 3.3 Summary of research output by Stumpel-Vos et al. (2013)

Name of study	*Focus measure evaluation results: UTR 4.1 Mobility management policy*
Author	Stumpel-Vos et al., 2013
Country	The Netherlands
Purpose	Shift: Evaluation of mobility services programme directed to employees from private companies in Utrecht.
Intervention type	Primary intervention: Incentives (free travel pass available from 2008 to 2011; study ran for 8 months).
Method	Baseline and follow-up surveys.
Evidence type	Cohort study.
Result	A calculation shows a total decrease of 2,880 car trips in the morning rush hours (from 6 am to 10 am per working day, 2011).
Mode shift related outcome	Decreased car use.
Context of the study	Urban. Initiative was conducted to address expected challenges, such as traffic congestion, of a major plan to upgrade existing transport infrastructure. The initiative needed the active support of private companies in Utrecht's area of intervention. Shuttle bus from local companies to PnR stations, train stations, etc were provided. An extensive communication campaign was also deployed.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – No.
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable. Requires there to be viable alternative travel options.
Design notes for New Zealand	Take advantage of planned major travel disruptions (eg, from infrastructure upgrades) to put alternatives in place. Could be relevant to Tier 2 urban environments with large employers if alternatives (eg, shuttles) can be provided.

In Germany, a randomised controlled trial assessed the impact of a material incentive (a free one-day bus ticket) as a primary intervention to increase the use of public transport among a group of people moving to Stuttgart. The intervention included the participants receiving tailored information and sources about the city's transport services and how to reach its shopping, leisure, and cultural facilities (Bamberg, 2006). Participants were randomly assigned to a control and an experimental group. Of the 241 participants who took part in the first stage of the study, 191 had actually moved to Stuttgart. Participants in the experimental group (*n* = 92) received the intervention 6 weeks after the move. About 12 weeks after the move all participants receive a second survey. The experiment found a statistically significant increase, from 18% to 47%, in the use of public transport among movers from the intervention group. Conversely, in the control group the change was small and statistically insignificant (from 18% to 25%). While the study did not include an assessment of the impact of the city's public transport network, the author pointed out that the services were regarded as 'high quality' (Bamberg, 2006). See Table 3.4 below for a summary of the intervention.

Table 3.4 Summary of research output by Bamberg (2006)

Name of study	*Is a residential relocation a good opportunity to change people's travel behaviour? Results from a theory-driven intervention study*
Author	Bamberg, 2006
Country	Germany
Purpose	Shift: Increase use of public transport.
Intervention type	Primary intervention: Material incentive (free one-day bus ticket). Secondary: Tailored information and advice.
Method	Two surveys administered to control and experimental groups.
Evidence type	Randomised controlled trial.
Result	Increase in public transport use from 18% to 47%.
Mode shift related outcome	Increased public transport trips.
Context of the study	Urban. Intervention targeted a very specific group of public transport users (movers). Public transport services system in Stuttgart regarded as 'high quality'.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – No.
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable but requires there to be viable public transport travel options.
Design notes for New Zealand	Unlikely to be adequate levels of public transport in Tier 1. Students moving cities are a potential audience. Likely enhanced impact by extending free travel beyond one day.

In contrast to the above-mentioned study, the impact of free bus tickets was tested for a longer period in an experiment conducted in Japan. The authors, Fujii and Kitamura (2003), focused on university students from Kyoto who were all car users. The intervention consisted of providing a one-month free ticket to the intervention group (*n* = 23). It was hypothesised that the material incentive would induce a lasting increase in participants' public transport use. Data was collected through surveys and the measures included travel mode frequency, travel habit, and perceptions and attitudes about car and bus use. The study found an increase in bus use, from 4.13% in Phase 1 to 9.34% in Phase 2. However, a decrease to 4.95% was registered later in Phase 3 when the free ticket expired. The habit of car use was significantly weakened in Phase 3 of the study, which, according to the authors, might suggest that the intervention could be utilised in

order to unfreeze habits of car use (Fujii & Kitamura, 2003). Table 3.5 provides further details of the experiment.

Table 3.5 Summary of research output by Fujii and Kitamura (2003)

Name of study	*What does a one-month free bus ticket do to habitual drivers? An experimental analysis of habit and attitude change*
Author	Fujii & Kitamura, 2003
Country	Japan
Purpose	Shift: To investigate whether a one-month free bus ticket would induce a lasting increase in drivers' public transport use in Kyoto.
Intervention type	Primary intervention: Material incentive for one month. Secondary intervention: Information and advice.
Method	Three questionaries administered to control and experimental groups.
Evidence type	Randomised controlled trial.
Result	There was significant increase in the mean frequency of bus use from 4.13% to 9.34%. However, in Phase 3, the mean of frequency decreased to 4.95% (this was also statistically significant).
Mode shift related outcome	Increased bus use (then it decreased after the ticket expired).
Context of the study	Urban. Targeted students from Kyoto University who reside in the city and use their cars. No additional information about participants' commuting behaviour were provided – for instance, the average kilometres travelled from home to university.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – No.
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable but requires there to be viable public transport travel options.
Design notes for New Zealand	Consider targeting by catchments, and/or changed provision of public transport services.

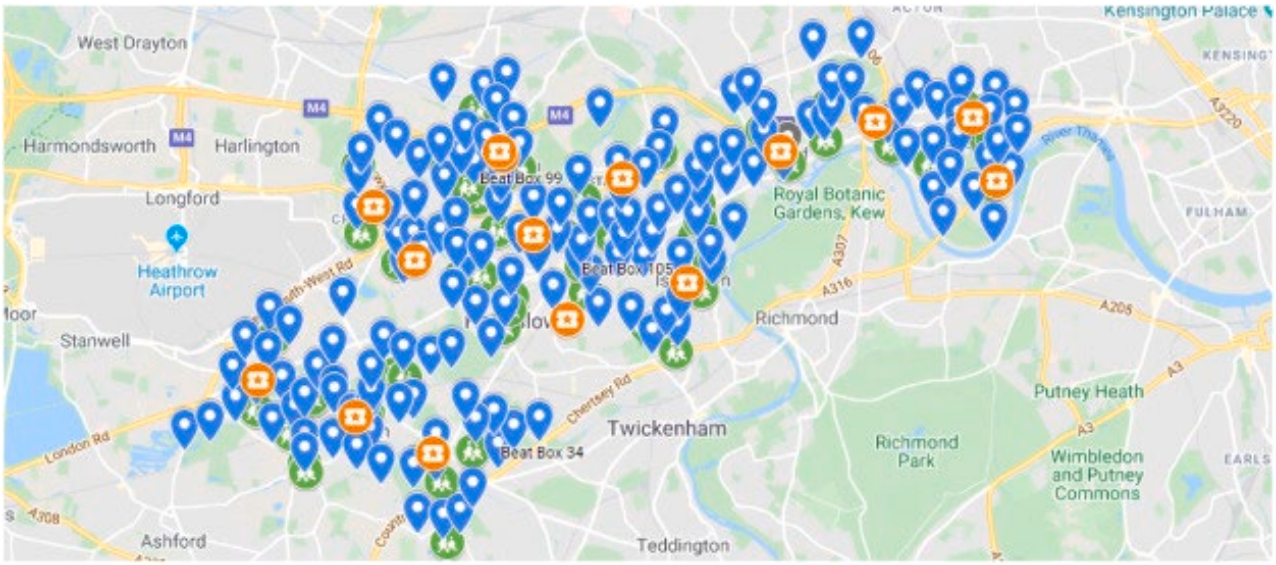
Gamification is an emerging method for incentivising change in transport behaviours through the use of game design elements in non-game contexts (eg, point scores, badges, leaderboards) (Nacke & Deterding, 2017). Some examples of the use of a gamified approach in the driving space include a number of apps (eg, TrueMotion Family, RoadReady, Life360 and DriveSmart) released by private technology businesses. Recent scholarly work on gamification in transport research has discussed and piloted its impact to enhance safer driving behaviours, improve driving skills or encourage eco driving (see Fitz-Walter et al., 2017; Günther et al., 2020; Rodríguez et al., 2014; Sezgin & Lin, 2019; Steinberger et al., 2017). However, despite the emerging body of research, there is a paucity of evidence on the effectiveness of gamification in terms of reducing LVT.

We only identified one study that used gamification to encourage mode shift (see Harris & Crone, 2021). The study looked at Beat the Street, a national programme funded by The National Lottery and delivered by a UK-based health-technology company called Intelligent Health Ltd. The study evaluated the impact of the programme on increasing active travel. The study's participants were aged between 19 and 79 and living in the London borough of Hounslow. The gamified approach of the programme allowed participants to acquire points based on how far they walked, ran and cycled, by tapping their radio-frequency identification card on various hotspots (using scanners) in their area (see Figure 3.2 and Figure 3.3). Prior to the intervention, participants were encouraged to register their radio-frequency identification card via an online portal that

allowed them to select a team to join. During registration, these participants (*n* = 3,173) completed a self-report questionnaire that included socio-demographic questions and a validated physical activity measure. At the end of the game, those who agreed to be contacted (*n* = 1,687) were sent a link to a follow-up survey via email. Complete data on physical activity at baseline and follow-up was available for 346 adults. Data obtained through gameplay provided a measure of intervention engagement. The study also gathered traffic count observations provided by a traffic monitoring camera installed in a key road. Based on the results, the authors concluded that the intervention helped to reduce car use and increase physical activity. They found that during the intervention, 53% fewer cars and vans were monitored travelling along a target road during morning commute times. Meanwhile, during afternoon commute times, the reduction was 33% for cars and 20% for vans.

Figure 3.2 An example of a hotspot (scanner) (reprinted from Harris & Crone, 2021, p. 2)

Figure 3.3 Map of the hotspot infrastructure implemented throughout the borough of Hounslow (reprinted from Harris & Crone, 2021, p. 3)



While the results seem promising, the gamified intervention lasted only six weeks. Thus, the extent of its impact over a longer period is still unknown. Further research could assess the long-term effects of the intervention. Moreover, as gamification is still an emerging area of inquiry in transport research, expanding inquiry to its impact on mode shift would be a fruitful area for further work. Additional details of this intervention are provided in Table 3.6.

Table 3.6 Summary of research output by Harris and Crone (2021)

Name of study	*Using gamification to encourage active travel*
Author	Harris & Crone, 2021
Country	England
Purpose	Shift: To assess the impact of programme promoting active travel.
Intervention type	Primary incentive: Gamification in a six-week game (the whole programme lasted 12 months). Secondary: Social/behavioural incentive.
Method	Survey data and data from radio-frequency identification reader.
Evidence type	Cohort study.
Result	During the intervention, 53% fewer cars and vans were monitored travelling along a target road during morning commute times, and 33% fewer cars and 20% fewer vans were monitored during afternoon commute times.
Mode shift related outcome	Decreased car use.
Context of the study	Suburban district in West London. Over 70% of participants were aged between 30 and 49, and three quarters were females. Only six-week duration. It seems relevant for short-distance commutes. Requires a partnership with IT industry.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – No.
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable but requires there to be viable alternative travel options.
Design notes for New Zealand	Determine local opportunities – for example, crunch locations in the network, and crunch times (eg, 'Mad March') and barriers such as weather.

3.2 Information and advice (including travel planning)

Implementing information campaigns or providing assistance with personal travel plans are often referred to as 'encouragement' or 'soft' measures in transport policy and research (Hiselius & Rosqvist, 2016). The purpose of soft measures is to avoid and/or reduce LVT and increase mode shift by motivating or influencing people's shift in travel behaviour towards the use of more sustainable modes of transport (Cairns et al., 2008). Of all the studies reviewed for this project, four applied soft measures such as information campaigns and travel planning as the primary or only type of intervention. Three of them targeted school-aged children from different jurisdictions such as Australia, Austria, Germany and Japan. In general, there is an indication that information campaigns aimed at mode shift work better when they are applied in conjunction with travel planning. Some (see Hiselius & Rosqvist, 2016) also suggest that, despite their potential, interventions based on these types of soft measures may need to be applied in combination with hard measures (eg, infrastructure improvements, congestion charges, restriction of parking spaces) in order to achieve the desired transport outcomes.

In Australia, the impact of a two-year programme was evaluated by Wen et al. (2008). The cluster randomised controlled trial targeted children aged 10–12 from 24 primary public schools in inner West Sydney. The study included students' families. The primary intervention was the provision of tailored information and advice to the participants, which comprised classroom activities, development of school travel access guides, teachers' professional development, and parent newsletters. The programme also involved working with local councils to improve safety and walkability of participating schools and their surroundings; however, the extent of these developments was not detailed by the authors. Furthermore, there were some differences among the participating schools, including their size, access to public transport, level of nearby traffic congestion and the socio-economic status and cultural mix of students. Data from two surveys was collected from the students and their parents (*n* = 1,996). The findings based on the parent survey data show an increase in walking activity. In this respect, 28.8% of students in the intervention group increased their walking, compared with 19% in the control group. However, this effect was not evident in the student data (Wen et al., 2008). Additional details of the intervention are provided in Table 3.7.

Table 3.7 Summary of research output by Wen et al. (2008)

Name of study	*Increasing active travel to school: Are we on the right track? A cluster randomised controlled trial from Sydney, Australia*
Author	Wen et al., 2008
Country	Australia
Purpose	Avoid/Reduce & Shift: To assess the impact of a programme on school children aged 10–12 and their active travel decisions.
Intervention type	Primary intervention: Information advice (a two-year multi-component programme including classroom activities, school travel access guides, parent newsletters and improved walking environment). Secondary intervention: Safety infrastructure upgrades.
Method	Baseline and follow-up surveys administered to students in the control and experimental groups.
Evidence type	Randomised controlled trial. The positive impact of the intervention was not evident on the student data. Other factors to be explored are changing local environments and parents' travel to work.
Result	Parents' survey shows 28.8% of students in the intervention group increased their walking, compared with 19% in the control group.
Mode shift related outcome	Increased walking activity.
Context of the study	Urban. Large city. Twenty-four primary public schools in inner West Sydney. Participating schools differed in terms of size, access to public transport, level of nearby traffic congestion and the socio-economic status and cultural mix of students. Study included children's parents.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes.
Transferability to New Zealand	☆☆ – Needs local infrastructure upgrades. Requires there to be upgrades to local active transport infrastructure if not already happening.
Design notes for New Zealand	Likely to be enhanced impacts with a co-design approach (see Chapman et al., 2020, below).

Another study assessing the impact of travel planning on reducing car use was reported by Fujii and Taniguchi (2005) in Japan. The authors assessed the impact of a travel planning and feedback programme and compared it with a traditional travel information approach. The intervention took place in one elementary school in the city of Sapporo and included 292 students aged 10–11 as well as their families. During a week, a group of students received individualised information and advice about reducing family car use (see Figure 3.4 for an example of the diagnostic checklist used). At the same time, another group was asked to develop behavioural plans to modify car trips. The most significant finding regards those participants who made behavioural plans. Reductions of 27.7% in terms of total trip duration and 11.6% in terms of car-use days were reported for this group (Fujii & Taniguchi, 2005). While the findings are promising, no further details about the context of the study were provided such as characteristics of the participating school and the households or the city's public transport system and its services/infrastructure supporting other modes of transportation. Table 3.8 provides further details of the intervention.

Figure 3.4 Example of diagnostic checklist (Fujii & Taniguchi, 2005, p. 388)

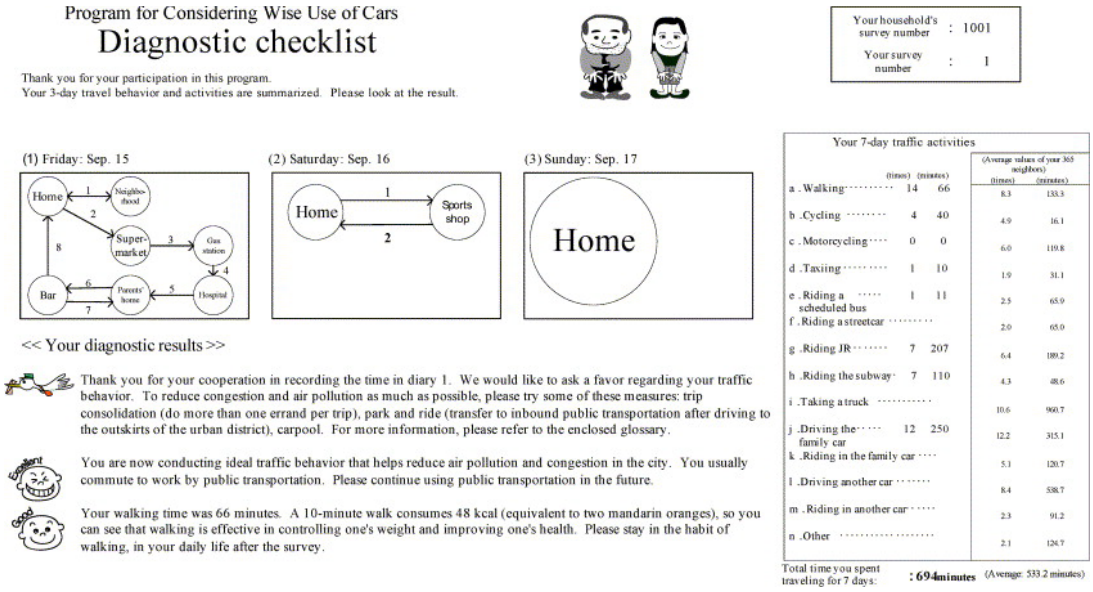


Table 3.8 Summary of research output by Fujii and Taniguchi (2005)

Name of study	*Reducing family car-use by providing travel advice or requesting behavioural plans: An experimental analysis of travel feedback programs*
Author	Fujii & Taniguchi, 2005
Country	Japan
Purpose	Avoid/Reduce: To compare the impact of two approaches to travel planning and feedback on home-based car trip. The study targeted high school students and their families from one school in Sapporo.
Intervention type	Primary intervention: Active participation in travel planning and advice. Secondary: Social/behavioural incentive.
Method	Baseline and follow-up surveys. Activity travel diary. Study ran for three months.
Evidence type	Randomised controlled trial.

Result	Participants who made behavioural plans to reduce car use actually made such reductions. The reduction was 27.7% in terms of total trip duration, and 11.6% in terms of car-use days.
Mode shift related outcome	Decreased car use.
Context of the study	One elementary school in an urban area. No further details about the characteristics of the households and school or the city's public transport system provided.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes.
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable but requires there to be viable alternative travel options.
Design notes for New Zealand	Tie to social and cultural imperatives such as sustainability and social cohesion.

Another experiment conducted with students produced inconclusive results about the impact of tailored information and advice in changing travel mode behaviour (see Stark et al., 2018). The intervention took place in four secondary schools in Austria and Germany and sought to promote active travel among participants in the experimental group (n = 90). It consisted of an information campaign through presentations in the classrooms by the researchers. The design of all campaign materials, presentations and activities were tailored to the age of the participants (12–14 years old). A key characteristic of the intervention programme was individualised treatment of the children, meaning that their actual travel behaviour served as the starting point for most of the materials, discussions etc. The study found that the intervention was effective in changing attitudes, perceived behavioural control and intentions to use non-motorised travel modes more and cars less. Nevertheless, the changes in intentions were weak predictors of changes in reported behaviour. The study did not provide further information about the characteristics of the participants. A summary and additional details regarding the experiment are provided in Table 3.9.

Table 3.9 Summary of research output by Stark et al. (2018)

Name of study	*The effectiveness of an intervention to promote active travel modes in early adolescence*
Author	Stark et al., 2018
Countries	Austria and Germany
Purpose	Avoid/Reduce & Shift: To promote active travel based on a travel awareness campaign intervention in four secondary schools.
Intervention type	Primary intervention: Tailored information and advice.
Method	Before-and-after questionaries. One-week travel diary.
Evidence type	Randomised controlled trial. Experiment ran for 12 months.
Result	Intervention was only effective in changing attitudes, perceived behavioural control and intentions to use non-motorised travel modes. Changes of attitude, subjective norm, and perceived behavioural control accounted for 29% (car passenger) to 92% (walking) of the variance in changes in intention.
Mode shift related outcome	Increased positive perceptions and intentions towards non-motorised travel modes and less car use. However, the changes in intentions are weak predictors of changes in reported behaviour.

Context of the study	The extent and quality of the public transport system differed between cities. No further details about the characteristics of the participants are provided. No new infrastructure needed.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes.
Transferability to New Zealand	N/A
Design notes for New Zealand	The inconclusive results about changes in behaviour mean that further evidence is needed before implementing in New Zealand.

On the other hand, in Sweden a field experiment looked for changing perceptions to reduce car travel via travel planning based intervention (see Eriksson et al., 2008). Seventy-one car users with an average age of 53 took part in the study. They were randomly assigned to a control and an intervention group. The intervention included a home-visit by one of the researchers. During the visit, the participants filled in a prospective car diary containing all the car trips they planned to perform the following week. Then, a list of different car reduction strategies (eg, changing travel mode, changing destination, cancelling trips, trip chaining, car-pooling) was presented to them. For each car trip, the participants had to decide whether they were willing to reduce car use on that particular trip or not. If they chose to modify their car trip, they were asked to indicate the strategy they planned to use and make a note of the changes in the prospective car diary. The study concluded that the intervention made the choice of travel mode more deliberate. The study also found that there were other reasons to reduce car use such as willingness to save money or to strive for a healthier lifestyle via active travel (Eriksson et al., 2008). Table 3.10 summarises key aspects of the intervention.

Table 3.10 Summary of research output by Eriksson et al. (2008)

Name of study	*Interrupting habitual car use: The importance of car habit strength and moral motivation for personal car use reduction*
Author	Eriksson et al., 2008
Country	Sweden
Purpose	Avoid/Reduce: To change car use habit via a moral motivation intervention.
Intervention type	Primary intervention: Travel planning. Secondary: Social/behavioural incentive.
Method	Before-and-after questionnaires. Travel diary.
Evidence type	Randomised controlled trial. Experiment ran for three months. Other reasons to reduce car travel (eg, willingness to save money or to strive for a healthier lifestyle via active travel) were found but not further investigated.
Result	Car users with a strong car habit and a strong personal norm were more likely to reduce car use compared to those with a weak car habit and a weak personal norm.
Mode shift related outcome	Made the choice of travel mode more deliberate.
Context of the study	Two non-specified urban areas in Sweden. Participants' average age was 53 for both experimental and control groups. No further information about the public transport system in the areas of study was provided.

Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes.
Transferability to New Zealand	☆☆☆ – Method needs adaptation.
Design notes for New Zealand	Requires adaptation to New Zealand car culture, notably in Tier 2 cities. Likely to be more effective in combination with incentives and good quality travel alternatives.

3.3 Congestion charging

Congestion charging or road pricing is defined as 'charging vehicles for use of specific roads during specific times and days, in order to reduce the severity and duration of congestion on the network' (Ministry of Transport, 2020, p. 3). Our review found positive impacts of congestion charging in congestion reduction in Gothenburg, Stockholm, London and Singapore. However, the extent of the reduction varied across these cities due to different conditions and need for additional actions. These included the level of maturity of the public transport system, provision of additional public transport, further infrastructure to support alternative modes of transportation, the topographical characteristics of sites of intervention, and/or the existence and impact of policies restricting car ownership. Another aspect outlined in the papers reviewed was that because charging drivers for road use can be contentious, there is a need for consultation with key stakeholders as well as political leadership during design and implementation of this sort of intervention.

In January 2006, Stockholm introduced a cordon-based congestion charging system with the purpose of improving air quality and reducing traffic congestion in Sweden's capital city. Vehicles travelling into and out of the cordon were charged for every passage during different hours of weekdays. The congestion charge system also consisted of extended public transport (16 new bus lines) and more PnR sites in the city and the county. The total public transport service was extended by 7% and the PnR capacity was extended by 29%. The system exempted from the charge taxis, buses, motorcycles, and cars classified as environmental vehicles (eg, driven by electricity or biofuels). An evaluation of the initiative was conducted by Johansson et al. (2009) via modelling of road traffic. To assess the impact of the initiative, traffic flow (eg, number of vehicles and road use) was calculated. Congestion was quantified based on floating car measurements or from traffic cameras. The study estimated a 15% reduction in total road use within the charged cordon while the reduction in total number of vehicle passages over 24 hours was 22%. The calculation also indicated that the reduction was lower during the morning peak period (16%) and higher during the afternoon/evening peak (24%). Regarding impact on emissions, the total traffic emissions in the cordon area of NO_x and PM_{10} fell by 8.5% and 13%, respectively.[6] While the findings are promising, they only measured the short-term impact of the scheme, making it difficult to know any lifelong outcome (Metz, 2018). Additional details of the congestion charging scheme are provided in Table 3.11.

[6] NO_x = oxides of nitrogen; PM_{10} = airborne particles less than 10 μm in diameter.

Table 3.11 Summary of research output by Johansson et al. (2009)

Name of study	*The effects of congestions tax on air quality and health*
Author	Johansson et al., 2009
Country	Sweden
Purpose	Avoid/Reduce & Shift: To assess the impact on road traffic of Stockholm's cordon-based congestion charge system introduced in January 2006.
Intervention type	Primary: Congestion charging. Secondary: Improved public transport services.
Method	Calculation of congestion was made based on floating car measurements or from traffic cameras.
Evidence type	Modelling.
Result	Fifteen percent reduction in total road use within the charged cordon. Reductions in traffic emissions were also recorded.
Mode shift related outcome	Decreased road use in area of intervention.
Context of the study	Urban. Large Swedish city. Extensive improvements in the city's transport services system (public transport services increased by 7%). New PnR infrastructure was also developed. Taxis, buses, motorcycles, and cars classified as environmental vehicles (eg, driven by electricity or biofuels) exempted.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – No.
Transferability to New Zealand	☆ – Would require major upgrades to ensure there are viable alternative travel options.
Design notes for New Zealand	Consider how journeys are affected by the topography and the shape of the city to determine boundaries. Political environment and social licence will be critical. Consider what is exempt, flow-on effects on traffic outside of boundaries, noise, historical precincts etc.

Based on the Stockholm's experience, Sweden's second-largest city, Gothenburg, introduced an adapted version of the congestion charge system in early 2013. The system used the same technology as in Stockholm, with automatic number plate recognition cameras taking pictures of vehicles' number plates (from ahead and behind). The registration number was identified directly in the camera using optical character recognition. Using a traffic modelling approach, Börjesson and Kristoffersson (2015) estimated the impact of the initiative on traffic congestion and the environment in Gothenburg. Compared to Stockholm, Gothenburg is a small to medium-sized city with less congestion and a lower public transport market share. Also, the objective of the charge system was to raise revenue (Börjesson & Kristoffersson, 2015). Data for the evaluation came from the automatic number plate recognition cameras. Survey data provided by the Gothenburg City Council was also used to analyse adaptation strategies among the drivers priced off the road. A two-wave panel travel survey was conducted in March–April 2012 and in March–April 2013. A key finding of the study was that car traffic across the cordon was reduced by 12% during charged hours. Also, survey data regarding adaptation strategies show that commuters priced off the road apparently switched to public transport (24% increase). Among discretionary travellers the main adaptation strategies were changing destination and reducing trip frequency (Börjesson & Kristoffersson, 2015). See Table 3.12 for additional information about the intervention.

Table 3.12 Summary of research output by Börjesson and Kristoffersson (2015)

Name of study	*The Gothenburg congestion charge. Effects, design and politics*
Author	Börjesson & Kristoffersson, 2015
Country	Sweden
Purpose	Avoid/Reduce & Shift: To assess the impact of an intervention (a time-of-day dependent cordon-based congestion charging scheme) aimed at reducing congestion and improving the environment. The scheme was introduced in January 2013.
Intervention type	Primary incentive: Congestion charging.
Method	Data from automatic number plate recognition cameras. Survey data provided by the city council.
Evidence type	Modelling.
Result	Traffic across the cordon was reduced by 12% during charged hours.
Mode shift related outcome	Decreased car traffic.
Context of the study	Urban. Small to medium-sized city in Sweden (Gothenburg). Limited congestion and lower public transport market share when compared with Stockholm and its congestion charging policy. The main objective of the charges was to raise revenue.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – No.
Transferability to New Zealand	☆ – Would require major upgrades to ensure there are viable alternative travel options.
Design notes for New Zealand	Consider how journeys are affected by the topography and the shape of the city to determine boundaries. Political environment and social licence will be critical. Consider what is exempt, flow-on effects on traffic outside of boundaries, noise, historical precincts etc.

The impact of congestion charging in other jurisdictions (ie, London and Singapore) have been compared by Metz (2018). For example, in Central London, where a congestion charge scheme was introduced in February 2003, it was found that the initial impact of the scheme was a 33% reduction in car traffic entering or leaving the charged zone. Although the charge was increased in 2005, the decision did not have a significant impact on traffic levels. In Singapore, the congestion charge scheme was upgraded from a paper licence to the Electronic Road Pricing system in 1998. The scheme included a central restricted zone (setting speed limits in urban roads and expressways) and relatively low charges on four additional zones with charges varying depending on vehicle class, time of day, and location. As a result of the introduction of the Electronic Road Pricing system, a reduction of 10–15% in traffic volume was reported in the central business district. Data on traffic speeds provided by the Singapore Land Transport Authority show that average speeds at peak hours on arterial roads and expressways were in line with the objectives of the initiative – around 28 km/h, and 60 km/h, respectively (Metz, 2018). Metz (2018) also summarised Stockholm's congestion charge scheme as reported by Börjesson and Kristoffersson (2015) – see above. One of the lessons from the positive outcomes (to different extents) of the three congestion charge initiatives, according to Metz (2018), is the role of effective political leadership, the appropriate use of technology based on number plate recognition, and the significant revenues generated. See Table 3.13 for further details.

Table 3.13 Summary of research output by Metz (2018)

Name of study	*Tackling urban traffic congestion: The experience of London, Stockholm and Singapore*
Author	Metz, 2018
Countries	England, Sweden, and Singapore
Purpose	Avoid/Reduce: To evaluate the impact of congestion charging in three cities around the world London (2003), Stockholm (2006), and Singapore (1998).
Intervention type	Primary intervention: Congestion charging.
Method	Use of existing publicly available data from the areas of study.
Evidence type	Review analysis of available data.
Result	In London the policy led to a 33% reduction of car traffic; however, congestion returned to previous levels over subsequent years. A similar initial decrease in traffic and delays was observed in Stockholm. In Singapore, where the cost of car ownership is substantial, charging has enabled acceptable traffic speeds to be maintained.
Mode shift related outcome	Decreased car traffic and congestion in the three jurisdictions studied.
Context of the study	Comparability of the effectiveness of the policy interventions is challenged by the differing characteristics of the cities/countries where they were implemented. Also, different measures were used to assess the effectiveness of each intervention. Singapore has schemes to limit private car ownership.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – No.
Transferability to New Zealand	☆ – Would require major upgrades to ensure there are viable alternative travel options.
Design notes for New Zealand	Consider how journeys are affected by the topography and the shape of the city to determine boundaries. Political environment and social licence will be critical. Consider what is exempt, flow-on effects on traffic outside of boundaries, noise, historical precincts etc.

3.4 Infrastructure development and improvements

This section is about reducing LVT with infrastructural interventions that enable mode shift. Lately, some literature reviews have been published assessing the degree of the impact of new or extended infrastructure on physical activity and mode shift (see Mölenberg et al., 2019; Panter et al., 2019; Stappers et al., 2018). One conclusion jointly reached by the reviews was that while infrastructural interventions have different levels of effectiveness (and in some cases were inconsistent), their outcomes depend on the way the evaluation has been methodologically designed (Mölenberg et al., 2019). In our review, we identified seven papers (some of which are recent and have not been included in previous reviews) that met our assessment criteria. In addition to methodological differences, the purpose of the interventions evaluated varied across studies (eg, increased walking, increased cycling, or both). The extent of the intervention also differed, with initiatives implemented in specific public or private settings such as avenues or workplace environments or in larger or multiple areas. A key aspect of the infrastructure intervention changing the road hierarchy intervention (Hosking et al., 2022) is that apart from hard measures it also included a participatory design where consideration of culture and identity played a critical role.

One study evaluated the impact of the Connect2 programme on promoting active travel (see Song et al., 2017). The five-year programme started in 2006 and consisted of developing new walking and cycling

infrastructure in 79 communities around the UK. The quasi-experimental panel study looked at changes in travel behaviour before and after the construction of the new infrastructure in three selected sites – Cardiff, Kenilworth and Southampton – noting that the physical improvements differed among the selected sites. In Cardiff, the new infrastructure consisted of a traffic-free pedestrian and cyclist bridge connecting to the city centre. Similarly, in Kenilworth, a walking and cycling bridge crossing a busy dual carriageway was implemented. Meanwhile, the new infrastructure in Southampton (see Figure 3.5) involved a raised boardwalk linking the city centre and nearby residential areas along the shore of the River Itchen. The study gathered travel behaviour data as well as personal and household information during late spring/early summer in 2010, 2011 and 2012 from a sample living around the selected sites. The key measures of the study were distance from the infrastructure and actual usage of the infrastructure. The study found that the experience of using the infrastructure was, overall, positively associated with a shift from private car use to walking and cycling. However, some differences were found between the three selected sites in terms of total travel time, and total distance travelled. For instance, Southampton registered the largest changes towards active travel mode. In Kenilworth, a similar pattern of mode shift was found, but not to the extent of Southampton. On the contrary, in Cardiff, active travel decreased and driving mode share increased. Song et al. (2017) also pointed out that, despite the encouraging results, the impact of new walking and cycling infrastructure on mode shift may be for recreational purposes rather than utility journeys, at least in the medium term. The study found that distance from the intervention did not directly and independently predict mode shift. Table 3.14 also provides additional information about the study.

Figure 3.5 Example of intervention area in Southampton – before (July 2009) and after (August 2011). Photographs by Yena Song (Song et al., 2017, p. 322).

Table 3.14 Summary of research output by Song et al. (2017)

Name of study	*New walking and cycling infrastructure and modal shift in the UK: A quasi-experimental panel study*
Author	Song et al., 2017
Country	UK
Purpose	Shift: To assess the effectiveness of new infrastructure interventions in promoting walking and cycling in Cardiff, Kenilworth and Southampton.
Intervention type	Primary intervention: Infrastructure intervention for active travel. Infrastructure developed between 2010 and 2011. The programme implemented infrastructure improvement in the UK between 2009 and 2013.
Method	Baseline and follow-up surveys.
Evidence type	Panel/cohort study. Data collected in spring/early summer in 2010, 2011 and 2012. Along with the use of new infrastructure, the loss of employment, higher education, being male and being part of the ethnic majority were consistently found to be significantly and positively associated with mode shift towards walking and cycling.
Result	Experience of using the new infrastructure was positively associated with a mode shift from the private car towards walking and cycling. On the other hand, distance from the intervention did not directly and independently predict mode shift, suggesting that passive or potential exposure to the new infrastructure may not have been sufficient to cause a mode shift.
Mode shift related outcome	Shift to active travel modes.
Context of the study	Urban. The planned infrastructure was not fully implemented at the time of the study.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – No.
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable.
Design notes for New Zealand	Requires there to be viable alternative travel options.

A New Zealand based study has also found a positive impact of new infrastructure on mode shift, namely active travel (see Chapman et al., 2020). The before–after quasi-experimental study investigated whether a combined central and local government funded initiative promoting active travel managed to change travel patterns of residents in New Plymouth and Hastings. Known as the Activating Communities to Improve Vitality and Equality (ACTIVE) programme,[7] the initiative aimed to provide safe urban environments that would encourage active travel, particularly among students and workers via fully integrated walking and cycling transport networks. ACTIVE focused on both students and workers through fully integrated walking and cycling transport networks. In Hastings, to link the city to surrounding centres, the funding allocated by the ACTIVE programme was invested in developing four arterial paths (29.5 km) and connecting them with more than 50 km of marked on- and off-road walking and cycling 'collector' facilities. The funding was also used for a marketing campaign. Meanwhile, as New Plymouth already had an extensive network of tracks,

[7] See https://www.sustainablecities.org.nz/our-research/past-research/resilient-urban-futures-programme/active-evaluation-cycling-and-walking

the allocated funding was used to connect and upgrade existing paths and to create an additional 12 km of off-road facilities and more than 20 km of on-road marked cycle lanes. Other interventions in New Plymouth included installing cycle parking, widening path entries, creating a number of shared spaces with reduced speed limits for vehicles (30 km/h), substantial media campaigns and events, and cycle-skills training at local schools (Chapman et al., 2020). The two intervention cities have similar characteristics (eg, physically close, similar climatic conditions, relatively similar transport characteristics). On the other hand, while the control cities (Whanganui and Masterton) were interested in encouraging active travel, they did not receive additional central government funding for this purpose. Baseline measures were taken in 2011 and follow-up measures in 2012 and 2013. Face-to-face surveys measured walking and cycling along with awareness, attitudes and habits. Explanatory and confounding factors for mode choice, including socio-demographic and wellbeing variables, were measured. The study found that the odds of trips being made by active modes (walking or cycling) increased by 37% (95% CI, 8–73%) in the intervention cities between baseline and post-intervention. The net proportion of trips made by active modes increased by about 30% relative to a background decline in active travel occurring in the control cities. The net 30% increase in active trips implies a 5.3% decrease in the relative number of motorised trips (Chapman et al., 2020). Further details of the study are provided in Table 3.15.

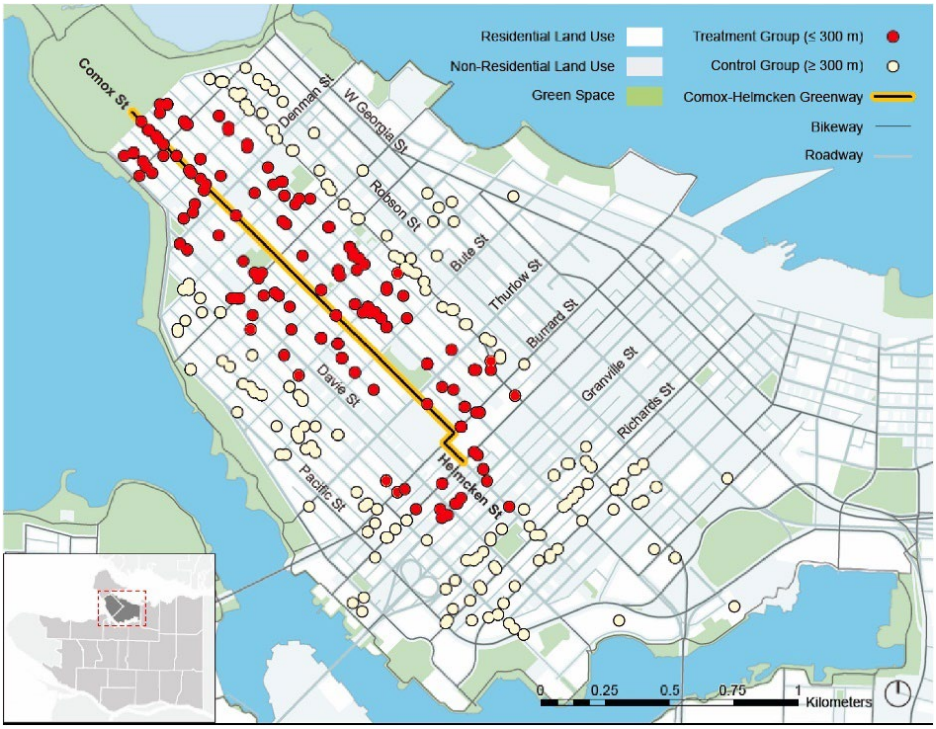
Table 3.15 Summary of research output by Chapman et al. (2020)

Name of study	*A cost benefit analysis of an active travel intervention with health and carbon emission reduction benefits*
Author	Chapman et al., 2020
Country	New Zealand
Purpose	Shift: To evaluate whether a combined central and local government funded initiative to promote active travel (cycling and walking) changed travel patterns of residents in New Plymouth and Hastings.
Intervention type	Primary intervention: New and extended infrastructure implemented between 2011 and 2012. Secondary intervention: Information and advice. In Hastings, new infrastructure consisted of four arterial paths (29.5 km) connected with more than 50 km of marked on- and off-road walking and cycling 'collector' facilities. In New Plymouth, funding was used to upgrade existing paths and create an additional 12 km of off-road facilities and more than 20 km of on-road marked cycle lanes. Other interventions included media campaigns, new cycle parking, and shared spaces with reduced speed limits for vehicles (30 km/h).
Method	Analysis of the net costs and benefits of an active travel intervention in two control cities.
Evidence type	Empirical economic analysis.
Result	The odds of trips being made by active modes (walking or cycling) increased by 37% in the intervention cities. The net proportion of trips made by active modes increased by about 30% relative to a background decline in active travel occurring in the control cities. A decrease of 5.3% in the relative number of motorised trips.
Mode shift related outcome	Increased active travel. Decreased motorised trips.
Context of the study	Urban. Provincial cities. The programme included investment in infrastructure such as cycle paths, other walking and cycling facilities, cycle parking and shared spaces. Media campaigns and events (eg, Share the Road) and cycle-skills training were also delivered.

Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes.
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable but requires there to be street upgrades for active travel.
Design notes for New Zealand	Co-design an important element to enhance impact across the whole community.

In Canada, a three-year natural experiment study (see Frank et al., 2021) looked at the impact that an infrastructure intervention had on cycling in downtown Vancouver. Specifically, the study looked at whether cycling trips will increase after the opening of a greenway for residents living within 300 m of the facility compared to those living further away. The Vancouver's Comox Greenway was completed in June 2013 to become a major active transportation corridor extending east to west through downtown Vancouver (see Figure 3.6 and Figure 3.7). The 2-km route is located in Vancouver's West End neighbourhood, a dense and mixed-use residential and commercial area. The infrastructure incorporated a range of cycling facilities and other streetscape changes to improve the walking and cycling experiences of the neighbourhood's residents. The changes were intended to reduce the amount of motor vehicle traffic, improve the level of comfort for vulnerable road users, and reduce traffic stress for pedestrians and cyclists using the facilities.

Figure 3.6 Area of study, including location of participants' primary place of residence (reprinted from Frank et al., 2021, p. 5)



Participants were adults aged 18 and older who lived within 1 km of the greenway. They were assigned to either an experimental group (*n* = 239) made up of participants who lived within 300 metres of the greenway and were considered to be exposed to the intervention, or a control group (*n* = 285) made up of those whose residence was further away (up to 1 km) from the greenway. Data for the study was collected in October 2012 (baseline survey) and October 2014 (follow-up survey). Temperature data was retrieved from Environment Canada's weather monitoring station for the travel diary reporting period. The main finding of the experiment was that the new greenway facility resulted in a 251% increase in cycling trips for the experimental group compared to the control group, who lived further away, after confounding factors were

accounted for through modelling. In the experimental group, participants who identified as white reported 130% more cycling trips than participants who identified as non-white, and those aged 65 and older reported 79% fewer cycling trips than younger age cohorts. Car sharing reduced the number of cycling trips – residents with a car-share membership were 46% less likely to cycle after the greenway opened. This suggests that the growth in car-share membership during the study period may have reduced the beneficial effect of the greenway on cycling (Frank et al., 2021). For additional information regarding the study see Table 3.16.

Figure 3.7 Examples of sites of intervention (before–after) in the Comox-Helmcken Greenway (reprinted from Frank et al., 2021, p. 4)

Table 3.16 Summary of research output by Frank et al. (2021)

Name of study	*Build it and they will cycle: Causal evidence from the downtown Vancouver Comox Greenway*
Author	Frank et al., 2021
Country	Canada
Purpose	Shift: To assess whether cycling will increase after the opening of a greenway for residents living within 300 m of the facility in downtown Vancouver and whether car-share members were more likely to cycle compared to their non-carshare counterparts.
Intervention type	Primary intervention: New infrastructure intervention, active travel and car sharing. New cycling facilities included one-way shared on-street paths with counterflow lanes (22% of the route in terms of length), one-way protected (29%) paths, and two-way shared on-street (49%) paths.
Method	Baseline and follow-up survey. Temperature data. Two-day travel diary.

Evidence type	Natural experimental design. Conducted between 2012 and 2015.
Result	The new infrastructure resulted in a 251% increase in cycling trips for the experimental group (nearby residents living up to 300 metres from the greenway). However, residents with a car-share membership were 46% less likely to cycle after the greenway opened. This suggests that the growth in car-share membership during the study period may have reduced the beneficial effect of the greenway on cycling. Participants who identified as white reported 130% more cycling trips than participants who identified as non-white, and those aged 65 and older reported 79% fewer cycling trips than younger age cohorts.
Mode shift related outcome	Increased cycling in area of intervention.
Context of the study	Urban. Specific metropolitan area. The greenway was implemented in a 2-km route within a dense and mixed-use residential and commercial area. Participants were adults who lived within 1 km of the greenway.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes (if there are locations of sufficient density of destinations and residences).
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable.
Design notes for New Zealand	Needs to be connected to a wider network.

In Portugal, a new walking infrastructure was shown to increase pedestrian volume and perceived walking experience (Cambra & Moura, 2020). The built environment, which was part of the Eixo Central project in Lisbon, sought to improve walking conditions in three sites – two avenues connected by a plaza (see Figure 3.8). Each site had distinct improvements that included green spaces, sidewalks, outdoor seating, and redesign of allocated space for private cars, public transportation, parking and bicycles. A new cycling infrastructure was also built, and no changes in local transport services were made. The project was implemented from June 2016 to February 2017. The quasi-experimental before–after study assessed whether the new infrastructure enhanced walkability in pedestrian volumes and walking experience. Cambra and Moura (2020) collected pedestrian volumes and walkability data. They controlled for pedestrian volumes in two control groups from neighbouring locations where no other infrastructure interventions occurred. A before–after walkability assessment of the intervention area was performed. A baseline survey was conducted in June 2016, while a follow-up survey was administered in June 2017. The pedestrian volume increased, at different levels, in the intervention sites. The increase was particularly noticeable in the Saldanha section, where the new walking environment was more intense. No significant change was observed in the control areas. People reported a more satisfying walking experience following the intervention. A positive relationship was found between the magnitude of change in walkability and the changes in pedestrian volume and walking experience. Additional information about the study is provided in Table 3.17.

Figure 3.8 Area in the Eixo Central where new walking infrastructure was implemented (reprinted from Cambra & Moura, 2020, p. 3)

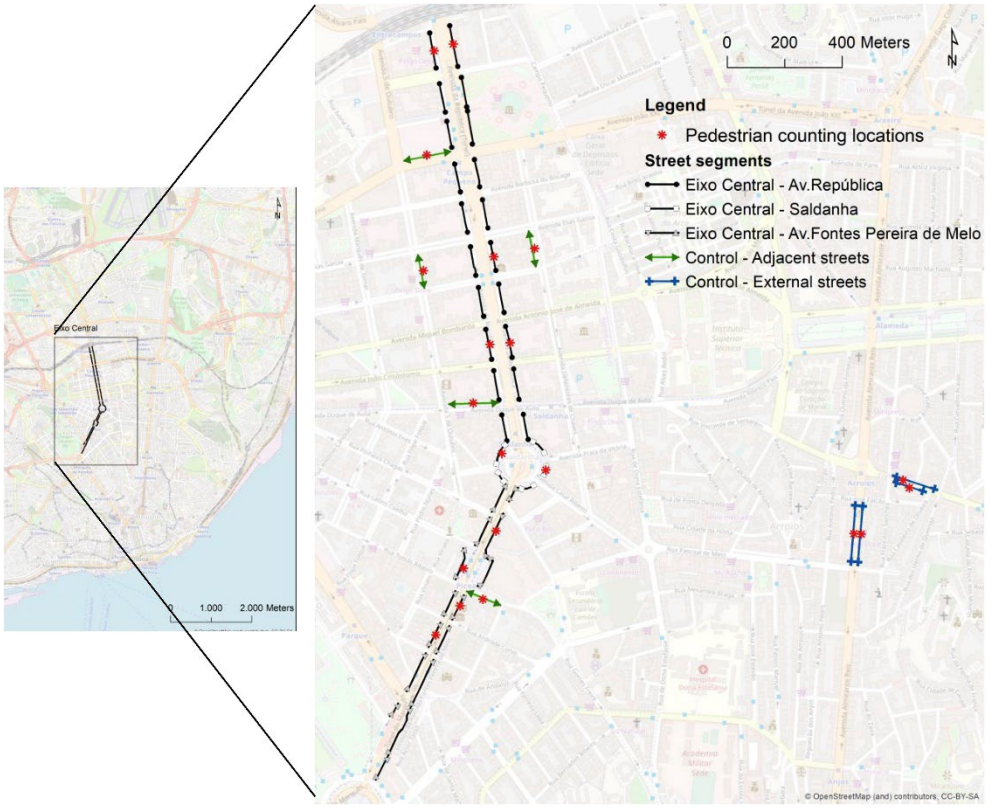


Table 3.17 Summary of research output by Cambra and Moura (2020)

Name of study	*How does walkability change relate to walking behaviour change? Effects of a street improvement in pedestrian volumes and walking experience*
Author	Cambra & Moura, 2020
Country	Portugal
Purpose	Shift: To evaluate the impact of new street infrastructure on walking in three sites – two avenues connected by a plaza – in Lisbon.
Intervention type	Primary intervention: Infrastructure intervention in the Eixo Central area. The implementation started in June 2016 and was finished in February 2017. Site 1: A 1,500 m long and 50 m wide avenue with dense occupation. Bus, underground lines and train available. Site 2: A 900 m long and 30 m wide avenue, with a relatively less dense occupation. Bus and underground lines available. Site 3: A round plaza (65 m radius) connecting sites 1 and 2 to other street links. New infrastructure was built in sites 1 and 2.
Method	Baseline and follow-up surveys.
Evidence type	Cohort study.
Result	The pedestrian volume increased in the intervention sites. In addition, people reported a more satisfying walking experience following the intervention. Perceived walking experience was higher in sites where more intense infrastructure changes were implemented.

Mode shift related outcome	Increased pedestrian volume and perceived walking experience.
Context of the study	Urban. Specific locations (two avenues connected by a plaza). Most participants were aged 20–34 (41%) and 35–65 (50%). In addition to providing an accessible pedestrian route, the intervention included more green spaces, sidewalks, and outdoor seating. Linked streets to the intervention area experienced changes in parking, public transportation and cycling. A new cycling infrastructure was also built in the intervention area. No changes were made to public transport services. No measures of changes in road traffic.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes.
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable in the context of town centre upgrades.
Design notes for New Zealand	Relevant to town centre upgrades.

The impact of infrastructure-based improvements (either free or paid-for) in the workplace setting has also been studied in the context of Cambridge in the UK (see Patterson et al., 2020). Specifically, the study looked at the associations between changes in the physical and social workplace environment and changes in commute mode over one year. Data came from the Commuting and Health in Cambridge study conducted with adults aged 16 years and older working in Cambridge. In 2011, participants (*n* = 419) completed a postal questionnaire about commuting practices, individual characteristics and workplace characteristics. A follow-up survey was completed a year later. In terms of the characteristics of the sample, on average participants were in the higher socio-economic status than the general population of England, with 67% having a degree, and 85% owning their home, neither of which differed by gender. Measures for changes in the physical environment of the workplace included the presence of bicycle racks, waterproof storage, a walk/cycle-to-work day, and car parking. Changes in the social workplace environment were measured as the modes of transportation used by colleagues and senior management to travel to and from work (ie, walking, cycling, and driving). Commute mode for the last seven days was also recorded separately for journeys to work and journeys from work, which included:

- guided bus
- other bus or coach
- train or underground
- car, taxi or van
- motorcycle or moped
- bicycle
- walking
- other.

The study found some gender-related differences. For example, an increase in active commuting was associated with improvements in the physical workplace environment among men, while a supportive social workplace environment was associated with improvements in women. In this sense, regarding males, changes in the workplace environment supporting active travel (ie, new or additional bicycle parking and/or shower facilities) were found to be associated with a 3.3% reduction in the proportion of commutes by private motor vehicle, and active travel among men increased by 4.4%. These associations were not seen in women. Additional information about the evaluation is provided in Table 3.18.

Table 3.18 Summary of research output by Patterson et al. (2020)

Name of study	*The social and physical workplace environment and commute mode: A natural experimental study*
Author	Patterson et al., 2020
Country	England
Purpose	Shift: To explore the associations between changes in the physical and social workplace environment and changes in commute mode over one year in Cambridge, England.
Intervention type	Primary intervention: workplace infrastructure improvements – ie, availability of bicycle racks, changing rooms, workplace car parking (free or paid-for).
Method	Baseline and follow-up surveys. Postal questionaries sent 12 months in between.
Evidence type	Natural experimental design.
Result	A physical workplace environment more favourable for active travel was associated with a 4% increase in the proportion of commute trips made by active commuting and a 3% reduction in the proportion of commute trips made by private motor vehicle among men, but this association was not seen in women.
Mode shift related outcome	Increased active travel. Reduced commute via private motor vehicle.
Context of the study	Urban. Study conducted with a sample of people living within 30 km of the city. Nearly 7 in 10 participants were females. Most (67%) had a degree. Participants were high in socioeconomic status; 85% said they owned their house. No further details of the characteristics of the workplace were provided.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes.
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable.
Design notes for New Zealand	Effect may be enhanced through incorporation into building standards and planning requirements, market quality signals. May be dependent on route quality and safety for women.

Aldred et al. (2019) studied whether and how proximity to active travel interventions is associated with changes in travel behaviour and attitudes, and change in attitudes to the local environment. To this end, the authors evaluated the impact of the 'mini-Hollands programme',[8] an initiative that implemented walking and cycling infrastructure in local settings. The evaluation centred on three Outer London boroughs: Enfield, Waltham Forest and Kingston (the programme was still in progress at the time of conducting the study). Compared to Inner London, Outer London had low levels of cycling and walking and was car dependent. The intervention in the three boroughs included pedestrian- and cycling-friendly street improvements. These were accompanied by redesigned town centres with cycle hubs, measures to reduce motor traffic in residential areas, and physically protected cycle lanes along the main road. At the time of conducting the study, a third of the planned infrastructure was complete or under construction. The intervention was further divided, a priori, into those living in 'high-dose neighbourhoods', where substantial changes to the local walking and cycling infrastructure had been implemented, and 'low-dose neighbourhoods' where such improvements had not (yet) been made. Participants (n = 1,712) were adults aged 16 and over who lived in Outer London, both in mini-Holland and non-mini-Holland boroughs. A baseline survey was conducted in May 2016, with a follow-up survey one year later. The study found that in the first year of the intervention there was an

[8] See https://www.london.gov.uk/what-we-do/transport/cycling-and-walking/transforming-cycling-outer-boroughs-mini-hollands-programme

increase in active travel among those living in areas where substantial infrastructure changes were implemented (ie, 'high-dose' neighbourhoods). Participants living in high-dose areas were 24% more likely to have done any past-week cycling at follow-up compared to those living in non-mini-Holland areas. The mid-point estimate for increase in active travel (walking plus cycling) time for the same group was an additional 41 minutes. There were also positive changes in views regarding local environments reported by the participants in intervention areas due to perceived improvement in cycling-related items (Aldred et al., 2019). Table 3.19 below provides further details about the study.

Table 3.19 Summary of research output by Aldred et al. (2019)

Name of study	*Impacts of an active travel intervention with a cycling focus in a suburban context: One-year findings from an evaluation of London's in-progress mini-Hollands's programme*
Author	Aldred et al., 2019
Country	England
Purpose	Shift: To examine whether and how proximity to new infrastructure in a specific area in London is associated with changes in travel behaviour and attitudes and change in attitudes to the local environment.
Intervention type	Primary intervention: Redesigned town centres with cycle hubs at tube and rail stations, measures to reduce and calm motor traffic in residential areas, and physically protected cycle lanes along main roads.
Method	Baseline and follow-up surveys.
Evidence type	Cohort study.
Result	One year's worth of interventions was associated with an increase in active travel among those living in 'high-dose' neighbourhoods (areas where substantial infrastructure changes were implemented). Participants in high-dose areas were 24% more likely to have done any past-week cycling at follow-up, compared to those living in non-mini-Holland areas. The mid-point estimate for increase in active travel (walking plus cycling) time for the same group was an additional 41 minutes.
Mode shift related outcome	Increased likelihood of any past-week cycling. Increased past-week active travel time.
Context of the study	Urban. Three boroughs in London. One intervention area had lower level of ethnic diversity. Another intervention area had lower rate of past-month cycling. Implementation of infrastructure was not fully complete in one intervention area.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – No (less bang for buck).
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable.
Design notes for New Zealand	Complex, long-term changes need council and public support to continue the plan over the construction period. Takes time for change to occur once improvements are completed. Impact enhanced by public transport infrastructure development.

A New Zealand based study evaluated the impact of Te Ara Mua – Future Streets programme[9] in Māngere (see Hosking et al., 2022). The main intervention of the project involved physical changes to the design of the roads so that the road hierarchy was more conducive to walking and cycling. Road hierarchy consists of

[9] See https://www.futurestreets.org.nz/

'the identification of different road categories within a road hierarchy and design of each road type to have a distinct "look and feel", with smaller local streets designed to achieve lower speeds without the need for posted speed limits and enforcement' (Hosking et al., 2022, p. 2). The aim of the programme was to make one of the largest suburbs in Auckland safer and to encourage walking and cycling among its residents. The suburb was selected for the intervention because it not only faces transport issues (ie, traffic injury rate higher than the city average) but also experiences other structural difficulties (ie, socio-economic deprivation and health inequities linked to structural racism) (Hosking et al., 2022). Along with the street hierarchy, the programme consisted of developing new infrastructure to improve sense of security in the areas of intervention such as walking and cycling facilities, plantings, wayfinding elements, and references to local and indigenous culture. The programme was implemented mostly between 2015 and 2016, with one further road treated in the first half of 2017. The purpose of the study was to identify pre–post changes in vehicle travel in the Future Streets intervention area (Māngere Central), compared to a nearby control area (Māngere East) (see Figure 3.9). A key aspect of the study was consulting with key stakeholders (particularly, city council, the local community, and other safety, disability, indigenous and walking and cycling communities and networks) during the design stage of the study. The findings show a positive impact of the intervention on car traffic speed. Compared with the control area, the study found post-intervention mean speed reductions of 8 km/h on local streets, and 5–6 km/h on collector streets. Mean traffic volumes reduced by 17–24% on local streets, with no change on collectors or arterials. Both post-intervention time points showed similar results, indicating a sustained effect. Traffic volume reductions were only observed in local streets in the intervention area, but not on arterial or collector streets (Hosking et al., 2022). Further information about the intervention is provided in Table 3.20.

Figure 3.9 Street hierarchy intervention in Mascot Avenue for the Te Ara Mua – Future Streets programme (reprinted from Te Ara Mua – Future Streets, n.d., interactive map[10])

Mascot Avenue near the Town Centre

Note: The pictures were taken from the middle of Mascot Avenue (near the town centre) looking south towards Massey Road. The 'after' photo shows that separated cycle lanes were installed on each side of the road. As the road was narrowed, car traffic was slower. Additionally, the footpath was upgraded.

[10] See https://www.futurestreets.org.nz/what-were-the-changes-before-after/

Table 3.20 Summary of research output by Hosking et al. (2022)

Name of study	*Effects of Te Ara Mua – Future Streets suburban street retrofit on traffic speed and volume: Controlled before-after study*
Author	Hosking et al., 2022
Country	New Zealand
Purpose	Shift: To identify changes in vehicle travel in the Future Streets intervention area (Māngere Central) compared to a nearby control area (Māngere East).
Intervention type	Primary intervention: Road planning/design (change of street hierarchy to restrict traffic). Secondary intervention: Infrastructure to improve sense of security in area of intervention. The intervention was implemented mostly in 2015 and 2016, with one further road treated in the first half of 2017.
Method	Data from tube counters in intervention areas, video data from road users.
Evidence type	Infrastructure intervention.
Result	Post-intervention mean speed reductions of 8 km/h on local streets, and 5–6 km/h on collector streets. Mean traffic volumes reduced by 17–24% on local streets, with no change on collectors or arterials. Both post-intervention time points showed similar results, indicating a sustained effect.
Mode shift related outcome	Reduced vehicle travel.
Context of the study	Urban. Provincial neighbourhoods. Māngere is one of the largest suburbs in Auckland. The suburb has long experienced transport and other structural inequities in New Zealand. Engagement of key stakeholders (including city council, the local community, and other safety, disability, indigenous and walking and cycling communities and networks) was critical for the study, particularly during the design of the intervention.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes.
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable.
Design notes for New Zealand	Relatively cost-effective. Co-design nature increases uptake. Complex, long-term changes need council and public support to continue the plan over the construction period. Takes time for change to occur once improvements are completed.

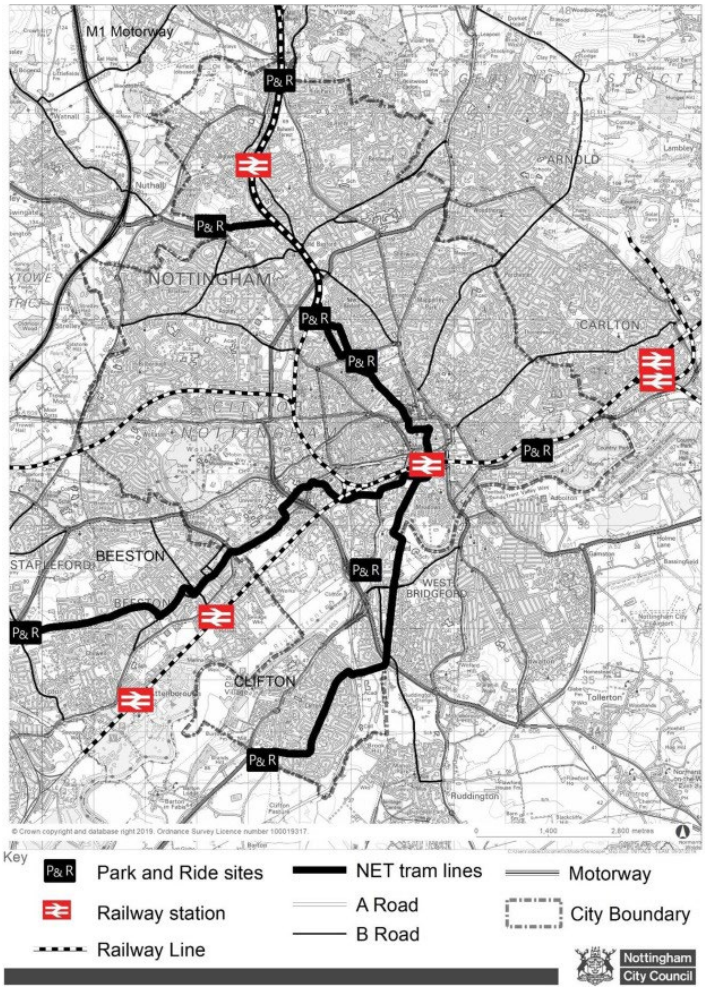
3.5 Car parking

This section of the report looks at interventions applying workplace car parking to avoid and reduce LVT and parking use in congested areas. Workplace car parking was a local policy intervention applied in different jurisdictions around the world since the early 2000s (eg, Nottingham, Melbourne, Perth and Sydney). Our review of the literature has identified two recently published evaluations in the UK, specifically in Nottingham and Cambridge. This section also includes a review of a study assessing the impact of another type of economic pricing in Sweden (ie, economic disincentives) due to its relevance despite being published in 2002.

First, an evaluation of Nottingham's Workplace Parking Levy (WPL) found a positive impact of the car parking scheme in terms of decreased vehicle trips and change to sustainable travel modes (see Dale et al., 2019). In April 2012 Nottingham became the first UK City to implement the WPL. The scheme was set up to

charge employers who had over 10 liable workplace parking spaces within the city, and the revenues generated were used for public transport expansion (ie, two additional tram lines into the city). The objective of the scheme was to reduce congestion in the city by increasing the effective cost of commuting by car while also funding transport improvements that would incentivise mode shift. In the first five years, the WPL generated a revenue of £44 million to the city council. A map showing the area of intervention is presented in Figure 3.10. The evaluation conducted by Dale et al. (2019) included data from a survey collected in 2016 from 2,500 commuters in Nottingham. The survey was supplemented with data provided by the city council showing the changes to mode share for mechanised modes (car, bus, tram and motorbike), public transport patronage, and the number of cycle trips over time between 2007 and 2017.

Figure 3.10 Nottingham transport geography (reprinted from Dale et al., 2019, p. 750)



The study found that 8.6% of car-based commuters switched to sustainable modes between 2010 and 2016 at least in part due to the implementation of the WPL and/or the associated transport improvements. When looking at the data regarding travel mode among those who switched from driving a car, 13.1% of cyclists indicated that their decision was due at least in part to the introduction of the WPL scheme, while 4.2% said they did so because of the WPL as a standalone scheme. Percentages among bus users in this respect were 7.3% and 5.4%, respectively, while for train users 7.1% and 3.5%. Dale et al. (2019) point out that the data suggests an increase in the mode share of public transport from 2010 to 2017; however, they clarify that the increase was also registered prior to the introduction of the WPL scheme. A further rise in 2015/16 associated with the opening of NET Phase 2 (the two additional tram lines) was also identified based on

public transport patronage data. In addition, the study found evidence of commuters switching to the car away from other modes, suggesting a significant suppressed demand for travel by car, which may counterbalance some of the beneficial impacts of the WPL scheme (Dale et al., 2019). See complementary information about the study in Table 3.21.

Table 3.21 Summary of research output by Dale et al. (2019)

Name of study	*The impact of the Nottingham Workplace Parking Levy on travel to work mode share*
Author	Dale et al., 2019
Country	England
Purpose	Avoid/Reduce & Shift: To evaluate the impact of a policy intervention on reducing congestion and changing transport mode choice.
Intervention type	Primary intervention: Parking charge. Secondary intervention: New public transport services.
Method	Quantitative (self-reported survey, non-probability sample) and mode share data from the city council.
Evidence type	Before-and-after study. No control group. Use of other data from council.
Result	Between 2010 and 2016, 8.6% of commuters switched from travelling by car to sustainable modes.
Mode shift related outcome	Decreased vehicle trips. Contributed to change to sustainable travel modes.
Context of the study	Urban. Additional public transport services were added (two tram lines) and bus service improvements were made.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes (if there is congestion).
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable. Requires there to be viable alternative travel options.
Design notes for New Zealand	Consider the viable catchment regarding available alternative modes. Enhanced impact likely from improved active travel provision. Consider safety factors such as time of travel for shift workers. Consider supporting travel demand management programmes in private workplaces.

In another UK-based study, Knott et al. (2019) investigated whether changes in workplace car parking policies were associated with changes in commute mode. The study was conducted with adults aged 16 and over who worked in Cambridge and lived within 30 km of the city. Some aspects to consider for the study were that employees in Cambridge tend to commute to work by car less that the average in the UK, and that the city has a distinctive cycling culture (Knott et al., 2019). Longitudinal data was collected from a cohort sample via annual surveys administered between 2009 and 2012. Participants had a mean age of 43.3. On average they commuted 13.1 miles and, of all commute trips reported over a 7-day period, 25.1% were made exclusively by motor vehicle, 54.6% involved an active mode of travel and 11.7% involved public transport. Workplace car parking policy remained largely stable, with only 234 (14.6%) of 1,608 pairs of observations involving a change of policy. The main finding of the study was that relaxations of parking policies – in other words, less restrictive of motor vehicle use – were associated with higher proportions of commute trips made exclusively by motor vehicle. In this respect, the proportion of trips undertaken solely by motor vehicle was 11.4% higher. Meanwhile, rates for trips involving walking and/or cycling (−13.3%) or public transport (−5.8%) were lower. In contrast, reverse associations were identified following the

introduction of more restrictive policies; however, such associations were small in size and not statistically significant (Knott et al., 2019). Additional information about the intervention is provided in Table 3.22.

Table 3.22 Summary of research output by Knott et al. (2019)

Name of study	*Changes in workplace car parking and commute mode: A natural experimental study*
Author	Knott et al., 2019
Country	England
Purpose	Avoid/Reduce: The purpose of the study was to investigate whether changes in workplace car parking policies are effective in shifting behaviour in Cambridge, England.
Intervention type	Primary intervention: Car parking
Method	Longitudinal study. Three surveys administered annually.
Evidence type	Natural experimental design – a quasi-experiment.
Result	Relaxation of parking policy was associated with higher proportions of trips made by motor vehicle. The proportion of trips undertaken exclusively by motor vehicle was 11.4% higher, while rates for trips involving walking and/or cycling (−13.3%) or public transport (−5.8%) were lower.
Mode shift related outcome	Increased car use. Reduced active travel and use of public transport.
Context of the study	Urban. Study conducted with a sample of people living within 30 km of the city. Participants had a mean age of 43.3. On average they commuted 13.1 miles. Of all commute trips reported over a 7-day period, 25.1% were made exclusively by motor vehicle, 54.6% involved an active mode of travel and 11.7% involved public transport. Workplace car parking policy remained largely stable, with only 234 (14.6%) of 1,608 pairs of observations involving a change of policy.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – Yes (if there is congestion).
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable. Requires there to be viable alternative travel options.
Design notes for New Zealand	Demonstrates the importance of workplace carparking provision. Consider supporting travel demand management programmes in private workplaces. Consider incorporation into land-use planning. Consider the viable catchment with regard to available alternative modes. Consider safety factors such as time of travel for shift workers.

3.6 Other interventions

In this section we have included the evaluation of two interventions looking at pricing of driving and car sharing, respectively. Both initiatives were found to have a positive effect in reducing LVT. For the second intervention – car sharing – market demand is a key aspect to consider for its implementation. Further details are provided below.

In an experiment, the effect of economic disincentives on private car use was investigated in the context of the Swedish city of Gothenburg (Jakobsson et al., 2002). A total of 80 two-adult households were recruited for the study and assigned randomly to one control and three experimental groups. Participants in the experimental and control groups logged their car trips during one week before, one week during, and one week after treatment. Data was collected between January 1999 and April 2000; however, during major

holidays no data gathering was conducted as daily travel was expected to differ significantly. The households in the experimental groups were charged per kilometre of driving their car(s) during a designated period (2 and 4 weeks). Households agreed to pay back SEK 10 (approximately US$1.20) per 10 km of driving their car(s). This corresponded roughly to a 100% increase of the cost for driving. The study found that car use decreased but only during the time of the intervention. In this regard, more households in the experimental groups than in the control group reduced both weekly frequency of car use and driving distance. For instance, households who were charged per km of driving reduced their weekly frequency of trips as well as driving distance from 55% to 45% in both cases. Households who were charged and asked to plan car use registered a reduction of 10% in both weekly trip frequency and weekly driving distance. Additional details about the experiment are presented in Table 3.23.

Table 3.23 Summary of research output by Jakobsson et al. (2002)

Name of study	*Effects of economic disincentives on private car use*
Author	Jakobsson et al., 2002
Country	Sweden
Purpose	Avoid/Reduce: To investigate the effects of economic disincentives on private car use in Gothenburg.
Intervention type	Primary intervention: Economic pricing. The households in the experimental groups were charged per kilometre of driving their car(s) during a designated period (2 and 4 weeks). Households agreed to pay back SEK 10 (approximately US$1.20) per 10 km of driving their car(s). This corresponded roughly to a 100% increase of the cost for driving.
Method	Surveys administered to one control and three experimental groups.
Evidence type	Randomised controlled trial.
Result	More households in the experimental groups than in the control group reduced both weekly frequency of car use and driving distance. For instance, households who were charged per km of driving reduced their weekly frequency of trips as well as driving distance from 55% to 45% in both cases. Households who were charged and asked to plan car use registered a reduction of 10% in both weekly trip frequency and weekly driving distance.
Mode shift related outcome	Decreased car use (but only during the time of the intervention).
Context of the study	Urban. Participants were car users from two-adult households. Data was not collected at times of major holidays as daily travel was expected to differ significantly. Intervention only lasted few weeks. Two control groups were charged per kilometre of driving for 2 weeks. The third experimental group was charged for 4 weeks.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – No.
Transferability to New Zealand	☆ – Needs major upgrades. Requires there to be viable alternative travel options.
Design notes for New Zealand	The ‘punishment’ nature of the intervention would require investment in complementary ‘carrots’ or positive interventions, including viable alternative travel means for it to gain social licence and lasting duration.

Another study (see Cervero et al., 2007) evaluated the impact of the first four years of City CarShare, a car-sharing private enterprise, on travel behaviour and car ownership in the San Francisco Bay Area in California. The private initiative was launched in March 2001 on the premise of renting cars by the hour. City

CarShare gained steady popularity during its first 4 years. In this respect, the monthly number of reservations or formal leases (of unlimited duration by a City CarShare member) increased from less than 1,000 during the first year to over 5,000 by mid-2005. The study adopted a quasi-experimental approach and collected data from five surveys conducted every year (starting February 2001) with people who signed up to join the private initiative (members) and those who said they may join someday (non-members). Participants (members and non-members) were all confirmed residents of the San Francisco Bay Area. For this study a quasi-experimental approach was applied, and analysis involved regressions with a control group. Participants who were members of the programme were approached on point-of-departure car pick-up locations, which increased as the programme grew. Members also filled in a travel diary. The average age of the members of City CarShare was 39. Members who took part in the study had a median annual income above the census averages for the area. Fifty-four percent were females. The findings show that 29% of car-share members had gotten rid of one or more cars, and 4.8% of members' trips and 5.4% of their vehicle miles travelled were in car-share vehicles. Matched-pair comparisons with a statistical control group suggest that, over time, members have reduced total vehicular travel. However, most declines occurred during the first 1 to 2 years of the programme; 3 to 4 years after City CarShare's inauguration, earlier declines had levelled off (Cervero et al., 2007). For additional information regarding the study see Table 3.24.

Table 3.24 Summary of research output by Cervero et al. (2007)

Name of study	*City CarShare: Longer-term travel demand and car ownership impacts*
Author	Cervero et al., 2007
Country	USA
Purpose	Reduce: To assess the impact of a car-sharing private enterprise on travel behaviour and reduction in motorised travel in the San Francisco Bay Area, California.
Intervention type	Primary intervention: Car sharing.
Method	Longitudinal study. Five surveys administered annually.
Evidence type	Matched cohort study. Study evaluated first four years of the programme. While participants reduced vehicle travel, most declines occurred during the first two years of the programme.
Result	Twenty-nine percent of car-share members got rid of one or more cars; 4.8% of members' trips and 5.4% of their vehicle miles travelled were in car-share vehicles.
Mode shift related outcome	Decreased car use.
Context of the study	Urban. The average age of the members of City CarShare was 39. Members who took part in the study had a median annual income above the census averages for the area. Fifty-four percent were females.
Relevance to New Zealand	Tier 1 – Yes. Tier 2 – No (economies of scale?)
Transferability to New Zealand	☆☆☆☆ – Method immediately transferable.
Design notes for New Zealand	Dependent on private providers, which can potentially limit the ability to target key population groups, catchments etc. Consider barriers for families, lower income households. Consider council support (eg, car parking provision).

4 Intervention database and dashboard

One of the objectives of this project was to develop, based on the evidence collected, a database that can be used as a resource for determining standard LVT reduction interventions in New Zealand. We did so by implementing an online dashboard. To this end, the stocktake of interventions we identified for the literature review were recorded and organised in spreadsheet form. The content of the file was refined based on our inclusion criteria and quality assessment periodically. Once we finished this process, the file was transferred into an online dashboard. The online dashboard was developed with the technical support of WSP's Business Intelligence team. The steering group provided feedback and agreed on the type of information displayed on the dashboard. Power BI was used to deliver the online dashboard format.

4.1 Intervention dashboard

Among the characteristics of the online dashboard developed for this project is that it is easy to use as there is no need for specific technical expertise to use it. Another aspect is its functionality. In this respect the dashboard is an interactive tool that includes a number of features such as clickable change filters, and a world map to contextualise evidence collected.

Figures 4.1–4.3 show how the evidence collected has been populated in the online dashboard. For example, the dashboard includes searchability by intervention type and evidence type. It also provides geographic location via a zoomable world map. The map allows users to hover over the intervention to obtain an overview. Users are also able to click on the actual intervention title to access the metadata. In addition, the online dashboard offers the option to look through more detailed information around the 'Study Details', and 'More Information' sections, including the relevance and transferability of the interventions.

Figure 4.1 LVT Intervention Research dashboard screen capture

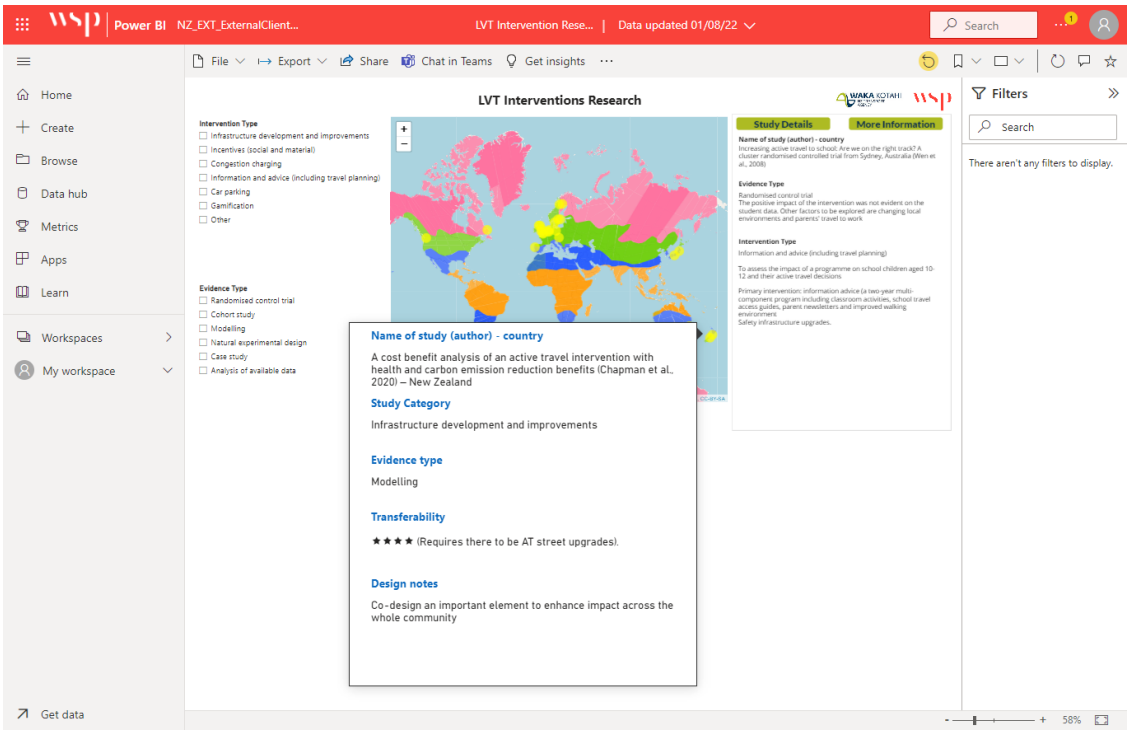


Figure 4.2 LVT Intervention Research dashboard – geographic location feature screen capture

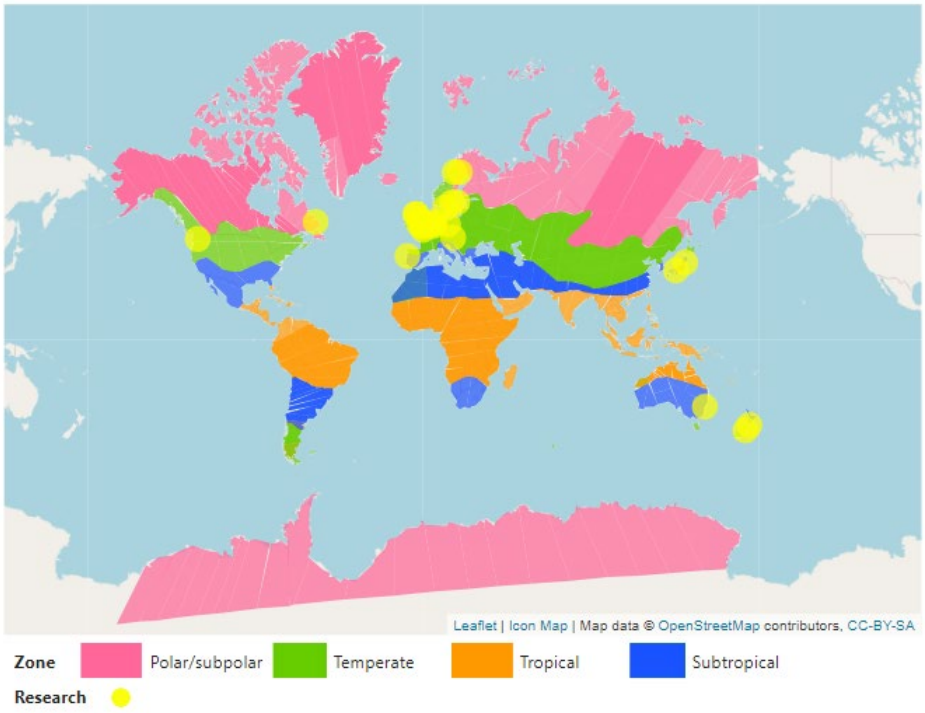
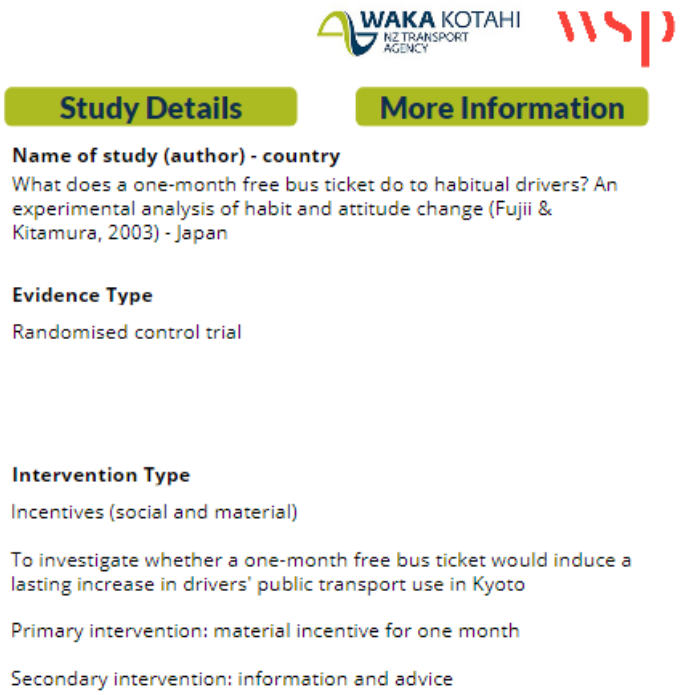


Figure 4.3 LVT Intervention Research dashboard – study summary screen capture



5 Non-intervention research insights

In section 2.3 we introduced the project's decision-tree research framework, a conceptual tool that guided our assessment of effective interventions to reduce LVT. In our search for relevant evidence, we also came across research outputs that did not meet our intervention criteria but still hold relevant insights and/or discuss knowledge gaps. These outputs fitted in the right-hand side of the decision tree. In this section we summarise key insights from this evidence.

One of the issues raised to better understand ways to reduce LVT is the impact of working from home (WFH), particularly due to the Covid-19 pandemic. Hensher et al. (2021) argue that transport models need to be adapted to current changes in the way that people live, work and move. They comment that integrated transport and land-use model systems have rarely incorporated flexible work practices. Considering the impact of Covid-related restrictions and lockdowns on ways of working, it has become a priority, according to the authors, to include WFH on mode choice and travel behaviour (eg, predicting the number of weekly days WFH and the time of day of travel). Others also point out the need to understand factors such as job characteristics (eg, office work) influencing time WFH (Brodeur et al., 2021) as well as people's demographic characteristics and their residential location (Barbour et al., 2021). Some (eg, De Vos, 2020) suggest that WFH can potentially contribute not only to less car traffic and congestion and an increase in recreational travel (eg, walking and cycling) but also less use of public transport and social isolation.

On the other hand, research also suggests that reducing the need to travel to access necessary services can also reduce traffic. In a review article, Purohit et al. (2021) specifically look at the effect of telemedicine, which is the provision of healthcare services at a distance via information technologies (World Health Organization, 2019). A key finding from the review of 14 studies was that, compared to face-to-face services, telemedicine (either videoconferencing or telephone consultations) lessens carbon footprint. The authors indicated that the benefit was mainly through travel-associated savings, which greatly outweighed the carbon footprint of the telemedicine equipment. The savings ranged from 0.70 to 372 kg carbon dioxide equivalent (CO_2e) per consultation but were also highly context specific, which included medical speciality, geography and time (Purohit et al., 2021).

Regarding research looking at PnR, a study reviewed the literature focusing on the effectiveness of these facilities. The review of 40 studies conducted by Zijlstra et al. (2015) found that an effective PnR facility predominantly attracts target group users; in particular, users who without this sort of facility would drive a car for their entire journey. Public transport mode and point of intercept are identified as the most important factors. The share of commuters, weekday or weekend use and the number of parking spaces have a significant but limited influence on the effectiveness. Another review of US-based evidence on PnR (see Haque et al., 2021) revealed that the majority of PnR studies were conducted in geographic areas with extensive transit services, most studies have focused on rail-based PnR facilities, and the most widely used analytical method was multinomial logit. Some areas for future research include studying remote PnR facilities, examining bus-based PnR facilities, and assessing the impact of emerging modes on PnR utilisation. This systematic review could assist planners and transit agencies in further improving sustainable PnR networks in their cities (Haque et al., 2021).

There is extensive literature examining the relationship between urban form, mobility behaviours, and wellbeing, including work undertaken in New Zealand. Overall, numerous studies have found that living in areas characterised as more walkable is associated with higher levels of physical activity (Smith et al., 2017). The International Physical Activity and Environment Network (IPEN) Adult Study examined the relationships between urban characteristics and physical activity in 14 cities over 10 countries (Cerin et al., 2014). The New Zealand cities included Christchurch, Wellington and Auckland (at the time, Waitakere and North Shore). The New Zealand arm of the IPEN Adult Study compared levels of physical activity (reported and

observed using accelerometers) amongst residents living in areas characterised as more or less walkable (Witten et al., 2012). While the study was cross-sectional, it was able to control for potentially confounding individual, household and neighbourhood factors, including self-selection factors. The study found that residents living in areas with more walkable, more aesthetically pleasing streetscapes and a greater density of local destinations tended to have higher levels of physical activity, much of which was transport-related walking. An approximately 30% difference in physical activity levels was seen between the most and least walkable neighbourhoods (Witten et al., 2012).

The research into the relationship between neighbourhood characteristics, mobility and wellbeing has shed light on the importance of accessibility to wellbeing resources. Urban form models such as 20-minute cities[11] demonstrate the potential of urban planning and design to reduce the dependence on private vehicle use and ownership by reducing the distance and time taken to get to everyday destinations. The 20-minute city approach (or 15 or 30 minutes, depending on the context) encourages us to re-think the spatio-temporal provision to communities of the opportunities to (a) participate locally in the workplace, education and play, (b) have access healthy foods, goods and services, and (c) participate socially and culturally, without needing to either drive or make journeys that take a long time using active or public transport. It emphasises the importance of considering how things work together, rather than thinking of individual buildings, modes or activities, so that it creates, in Baum and Palmer's (2002) terms, the 'opportunity structures' for wellbeing. Because of the necessary interaction between what is built and how people engage with structures and each other, the changes needed to retro-fit places such as Hamilton[12] into a 20-minute city will be comprehensive and complex.

[11] See https://thespinoff.co.nz/partner/wsp/05-07-2021/the-case-for-15-20-minute-cities-in-new-zealand

[12] See https://hamilton.govt.nz/your-council/news/growing-hamilton/a-20-minute-life-changer

6 Systematic reviews

Recent systematic reviews have attempted to examine the impact of various interventions on outcomes related to LVT reduction. Systematic reviews are useful for being able to provide an overall assessment of effectiveness and the quality of contributing studies, which provides insights into the overall generalisability of interventions. In systematic reviews, there is often a big focus on the methodological quality of a study as a means of increasing the confidence in the contribution of results to the overall quantification. However, such reviews are less able to provide information on the specific features necessary for successful interventions, and important factors such as relevance to the New Zealand setting. That is, systematic reviews can provide an answer to the question of 'Does X work?' but less so to the question 'Will this intervention work here?' With that in mind, the overall findings from recent examples are presented below.

Panter et al. (2019) undertook a systematic review to ask whether changes to the physical environment could promote more walking and cycling. The overall conclusion is that interventions addressing accessibility and safety were the most effective at promoting walking and cycling. However, of the 13 evaluations, most rated poorly on credibility, only two addressed the underlying mechanisms, and information about context was limited.

Mölenberg et al. (2019) undertook a systematic review of studies of infrastructural interventions to promote cycling. The outcomes of interest were changes in cycle behaviours and/or changes in the use of cycle infrastructure. Across most of the 31 studies reviewed, increases in both outcomes were reported, but with considerable variability (behaviours: 22% median relative change compared to baseline (range 21–262%); usage: 62% median relative change compared to baseline (range 4–438%)). The review did not discuss the importance of the type of infrastructural interventions for differences in cycling outcomes across studies.

The authors found that some of the variability could be attributed to the wide range of study methods used, which made comparisons difficult. For example, studies with subjectively measured outcomes tended to have larger changes than those using objective measurements (such as count data). Causal attribution of outcomes to infrastructure changes was also limited by lack of information and analysis of other changes that may explain or contribute to the observed outcomes. Cycling behaviour outcome studies were more likely than usage outcome studies to collect population characteristics, typically including age, gender and socio-economic status indicators. However, only three tested for differences in outcomes by population groups.

The authors note that the review was not able to provide insights into the extent to which increases in cycling outcomes could be related to decreases in LVT. In most studies there was no distinction between trip purposes, mode shift or traffic changes in how studies were assessed.

Wimbadi et al. (2021) reviewed urban experiments with public transport to support transitions to low-carbon mobility in cities. The systematic review mostly focuses on experiments to reduce carbon emissions through shifting away from fossil fuels. Few experiments aimed to promote mode shift to public transport through service and business practices (such as PnR) or citizen practices (such as information campaigns). The review does not report the impact of the experiments on mode shift or public transport uptake.

Semenescu et al. (2020) focused on studies aiming to reduce car use through 'soft' or 'encouragement' interventions. The overall estimate from the meta-analysis is for a 7% reduction in car use, which is similar to previous review findings. The type of intervention mattered for effectiveness. In descending order by effect size, they were:

- norms
- knowledge and awareness
- capability and self-efficacy.

Interventions addressing attitudes and habits on their own were less effective than when combined with other types.

Javaid et al.'s (2020) review of reviews established that interventions targeted at individuals can be effective at encouraging people to shift modes, but it is the changes in infrastructure component of an intervention that plays a greater part in mode shift. The authors make the case for multiple types of interventions interacting to achieve low-carbon futures.

Kuss and Nicholas (2022) undertook a systematic review with the explicit purpose of identifying lessons for implementing car use reduction interventions in a European city. Interventions were characterised by whether they were 'push' and/or 'pull', and whether they were geographically based interventions (eg, city centres) or targeted at populations (eg, commuters). The review also accounted for political aspects, such as the nature of stakeholder engagement – the review found that in most cases, local stakeholders (public and private) led the interventions. Notably, the types of interventions identified used multiple measures, including multiple policy types (between two and four for each intervention). In no cases were 'push' type interventions used without some sort of complementary 'pull' measure, and about half used 'pull' measures only. No commentary was provided on which combination was most effective.

7 The evidence conundrum

This review has highlighted the challenges of seeking evidence for interventions addressing complex drivers of behaviours such as light vehicle use. What does this mean for developing an evidence base of what works for reducing LVT in New Zealand? While this review has by no means been exhaustive, the paucity and variability of evidence we found has been well reported in other more comprehensive systematic reviews of similarly complex topics (see chapter 6 above). In this and other evidence reviews, there is a significant mismatch between what decision-makers want from evidence and what is available. This is not unexpected, however. Referring to a similar observed mismatch in disaster knowledge, Albris et al. (2020) referred to this mismatch as the 'epistemological gap' between the development of a knowledge base and how it is to be used. Different types of knowledge will have varying degrees of significance to different users:

> *While the output of scientific research is (ideally, at least) a nuanced recommendation based on probabilities and careful consideration of uncertainties, decision-makers are forced to follow a Boolean, binary logic when selecting policy options.* (Albris et al., 2020, p. 7)

To understand why this gap persists, it is worth considering how the process of evidence generation affects what is ultimately available to decision-makers. By and large, what counts as evidence, particularly high-quality evidence reported in academic journals, is more about reporting whether an intervention has worked rather than informing decision-makers about which intervention is most appropriate.

7.1 Evidence generation issues and implications

For evidence to be generated, data needs to available before, during and after an intervention. Failure to gather data on travel patterns before a change in infrastructure will make it difficult to assess the impact of an intervention. Changes need to be monitored for sufficient time and geographical scales to allow for behaviours to evolve and consolidate.

Generating evidence of interventions requires funding to support evaluation and reporting, either as part of the evaluation of an investment or as part of academic research. However, the competitive academic model will not necessarily be an appropriate avenue for a number of reasons. Evidence generated through the academic route is generally dependent on securing funding from highly competitive grants. Routine monitoring of change is unlikely to appeal to research funders without a novelty factor. Smaller-scale evaluations may be fundable as part of student-led research, which will favour the reporting of relatively simple, short-run interventions. Non-academic evaluations of interventions (such as infrastructure or policy changes) also require dedicated funding available before and after the intervention. Where behaviours might take time to 'bed in' in response to change, evaluation funding may need to be de-coupled from the final completion of, for example, a cycleway project. Multi-factorial interventions may require ongoing evaluations as programmes evolve and interact (Stappers et al., 2020). The challenge is in ensuring the design of evaluations will be appropriate to the intervention as well as providing a suitable level of robustness.

Similarly, reporting in peer-reviewed academic literature is restricted by a competitive publishing requirement. For a paper to be published in high-impact journals, it needs to be novel and 'moving the field forward' in some way. Within the academic world, there is a known publication bias against negative or null findings, meaning it is harder to contribute to the evidence base about what does not work. One way authors work around this is to focus on one part of an intervention that was successful, with less attention given to aspects with little or no change. Routine intervention evaluation reports are published in the 'grey literature' but are often less subject to quality controls in terms of methodology, what is included in the evaluation, and reporting protocols.

The publication process also filters what information is available. In particular, academic papers are typically constrained by word counts, which limit the amount of information presented. A decision-maker will want contextual information to evaluate the likely effectiveness and transferability of an intervention to another setting – 'Will it work here?' For example, how well would a mode-shift incentives programme work if there were minimal levels of safe and affordable active and public transport? Will an intervention targeted at suburban family households have a similar impact on a different household circumstance? In an inner-city household? Contextual information is also critical to being able to attribute the impact to the intervention. It requires information on the context to determine how much difference an intervention made compared with other factors happening at the same time.

And finally, the type of intervention can affect how easily it can be evaluated. Strategic-level, longer-term, more comprehensive interventions or changes will require more resources (funding), take longer to both implement and show results, and may come to less definitive conclusions than a randomised controlled trial, for example, that targets individuals. Longer-term, more complex projects are riskier and therefore typically less likely to be funded and implemented, and then able to be evaluated (Ogilvie, Adams, et al., 2020). Projects that engage closely with communities are also 'messy', and the intervention becomes part of the context over time and therefore harder to distinguish between the intervention and the outcome (Stappers et al., 2020). Yet they may be ultimately more effective at achieving mode shift in populations.

Because of the above factors, there are likely to be many more interventions undertaken than evaluated, and many more evaluated than accessible published reports. The risk is that a restricted evidence base in turn restricts the types of interventions that are funded.

7.2 Alternative ways of synthesising evidence

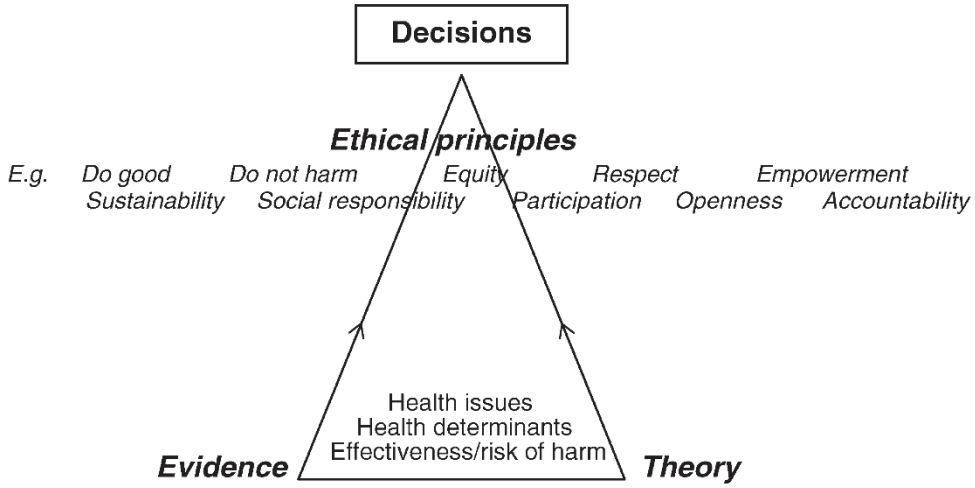
Recent commentaries have recognised the need for a different way of thinking about the role of evidence in making decisions about complex interventions. As noted above, systematic literature reviews all too often end up with a small number of studies that are not easily comparable or transferable to real-world settings. This is particularly the case when looking for interventions with goals such as mode shift that address complex environments and needing to reach across geographies, populations and cultures. Public health and health promotion researchers have a similar challenge of looking for evidence of effective interventions to tackle critical upstream determinants of health in complex environments. Tannahill (2008) argued that a reliance on traditional evidence hierarchy criteria is limiting what evidence is available for assessment and what meaning can be taken from them. For example, while randomised controlled trials are held up as the most methodologically robust study design, their findings do not always translate into effective interventions in real-world situations. This limitation is even greater when seeking evidence for the effectiveness of interventions that address complex environments. Alongside other points, two stand out as relevant lessons here:

> *The impossibility of securing all the evidence we would like to have to inform action makes it reasonable to use plausible theory, weighed up alongside available evidence, in health improvement decision-making. If decisions were only to be based on available strong evidence of effective actions, the result would often be a very small number and range of actions, with a risk of achieving less population health gain and less of an impact on health inequalities than would be achieved through a fuller set of measures devised on the basis of theoretical plausibility as well as evidence of effectiveness…*
>
> *[and]…comprehensive packages of actions can generally be expected to have more impact on population health than a narrower approach, but available effectiveness evidence largely relates to single interventions evaluated in isolation and does not shed enough light on the extent to*

> *which particular policies or other actions (even including some that appear ineffective when looked at in isolation) might have an impact when used in combination.* (Tannahill, 2008, p. 385)

Tannahill (2008) argued for the incorporation of theory and ethics, alongside methodological strength, as a means of determining what counts as 'effective'. He proposed a decision-making triangle for options to be considered against ethical principles, existing evidence, and theory (Figure 7.1).

Figure 7.1 The health improvement decision-making triangle (reprinted from Tannahill, 2008, p. 387)



While this review has not sought to prioritise so-called gold standard study methods such as randomised controlled trials, finding a way to recognise and give weight to a diverse array of study designs and intervention reports would be helpful.

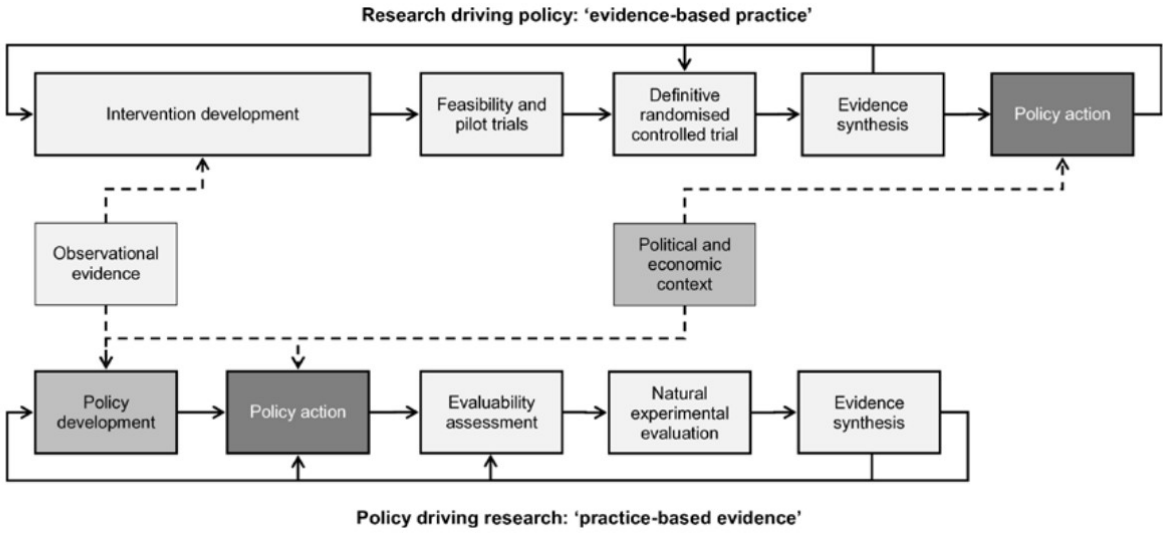
Ogilvie, Adams, et al. (2020) recognised the value of natural experiment evaluations for informing public health policy, and they identified lessons that are very relevant to the LVT reduction challenge. They argue that the 'primordial' interventions – that is, interventions that seek to eliminate health risk factors – operate at the population level by attempting to change the underlying environments that shape behavioural patterns. Examples referred to include changes to the built environment, and policy-level levers. Broader-reaching, population-focused interventions will have smaller effect sizes than targeted interventions, but the potential impact is greater because more people are affected. Therefore, reporting the effectiveness of an intervention by effect size can be misleading when considering the effectiveness of an intervention.

The evaluation of these types of interventions does not sit easily within the traditional rational, linear research-to-practice model, where multiple interventions are designed, tested, evaluated as more or less effective, and then the 'effective' ones implemented by practitioners (referred to as 'evidence-based practice') (Ogilvie, Adams, et al., 2020). They propose that 'practice-based evidence' also needs to be generated, where evidence of effectiveness arises from the multiple cases or actions that arise as changes are made in real life. Both pathways for generating and using evidence can work together (Figure 7.2). The authors put forward three implications for supporting primordial interventions through a more effective and useful evidence base:

1. Reducing critical uncertainties through accumulated knowledge (rather than definitive, hypothesis testing).
2. Including non-randomised study designs where they address the principles of a randomised controlled trial (ie, to reduce confounding), ensuring relevance to the real-world setting, and establishing plausibility of causal inference.

3. Thoughtful appraisal of how useful the evidence is, including consideration of internal validity (Ogilvie, Adams, et al., 2020).

Figure 7.2 Two complementary modes of evidence generation (reprinted from Ogilvie, Adams, et al., 2020, p. 205)



In a subsequent paper, Ogilvie, Bauman, et al. (2020) describe a 'mosaic' approach to developing an evidence base of interventions to address the upstream determinants of health, which includes transport, mobility, and urban form. Using a drystone wall metaphor, they say:

> *If conventional evidence synthesis can be thought of as analogous to building a wall, then we can increase the supply of bricks (the number of studies), their similarity (statistical commensurability) or the strength of the mortar (the statistical methods for holding them together). However, many contemporary public health challenges seem akin to herding sheep in mountainous terrain, where ordinary walls are of limited use and a more flexible way of combining dissimilar stones (pieces of evidence) may be required.* (Ogilvie, Bauman, et al., 2020, Abstract)

As above, they recognise the challenge of balancing internal validity of controlled study designs with the external validity of practice-based studies. They ask how we can improve the generalisability of the causal inferences made from real-world interventions so findings can reasonably be applied elsewhere (Ogilvie, Bauman, et al., 2020). Continuing to develop more sophisticated and thoughtful approaches to meta-analysis and data optimisation and modelling will be helpful in creating a bigger evidence base (the traditional brick-based wall building approach). However, expanding the drystone wall metaphor, they make the case for building an evidence base that optimises the unique shape and size of each stone, creating a synergy that the wall holds together (Ogilvie, Bauman, et al., 2020).

Ogilvie, Bauman, et al.'s (2020) mosaic approach to evidence synthesis embraces the eclectic nature of evidence, and takes a flexible and reflective approach. Three principles are proposed:

1. **Looking beyond interventions.**
   Rather than focusing on the form of the intervention, they recommend considering the functions – 'the processes and changes they provoke' (2020, p. 6) – that could be achieved in different ways, in different places.

2. **Searching for patterns.**
   Rather than seeking causal estimation from single studies, they suggest triangulating quantitative and qualitative study designs; experiments and process evaluations; and estimation and explanation intentions to generate understanding.
3. **Embracing the mess.**
   Rather than only looking for clarity and successful evaluation outcomes, they propose stepping back to see the diverging, contradictory results accumulated across a range of interventions to gain better understanding of what did and did not happen.

8 Discussion

This report presents findings from a narrative review of a collection of existing literature, supplemented with targeted searches of effective interventions to reduce LVT. A particular interest of this research project was to assess interventions by their relevance and transferability to Tier 1 and 2 urban environments in New Zealand.

The review took a pragmatic approach to locating, assessing and analysing interventions in order to provide timely advice, and in recognition that the work needed to undertake a full systematic or narrative review was beyond the scope of this project. Nevertheless, the range of interventions covered, and the overall insights gained about interventions, were comparable with systematic reviews using a more exhaustive approach to a specific aspect of LVT reduction or mode shift. The approach also recognised the relatively small number of available evaluations suitable for inclusion, as seen elsewhere. For example, a systematic review by Kuss and Nicholas (2022) found 24 studies that quantified reductions in car use out of almost 800 papers, of which only 10 were peer-reviewed studies. While the intention of the review was to assess study quality and document metrics such as effect sizes and spatial units to allow comparisons, the information available in papers was generally inadequate or highly variable between studies. Accordingly, we sought to provide additional insights by using a map-based dashboard to present findings, insights from relevant non-intervention research, recent systematic reviews, and commentaries addressing the evidence conundrum.

Our research strategy primarily used recent collections from complementary research projects conducted by WSP, including those collated by Waka Kotahi and Te Manatū Waka and made available to this project. This was complemented with ‘snowballing’ searches using academic databases. A total of 24 papers met our inclusion criteria. The selected evidence comes from multiple regions with most studies being conducted in Western Europe. The selected studies evaluated different types of interventions (eg, congestion charging, incentives, car parking) and applied various research approaches (from randomised controlled trials to cohort studies and modelling). The degree of positive impact reported and the outcomes reported also differ across the studies. The studies reviewed not only differed in terms of the research approach but also the types and/or combinations of data used, the analytical lenses applied, and the extent and context of the interventions reported and evaluated. Outcome measures varied considerably across the studies, limiting comparability. Because the primary focus of this review was on LVT reduction through avoiding/reducing trips and shifting from light vehicle use, we also included studies where mode shift was the primary outcome. However, it should not be assumed that an increase in walking trips (for example) would result in an equivalent decrease in car trips. The outcome measures reported were also dependent on what kind of travel data was collected. In this respect, self-reporting survey data was primarily collected in most studies (except for those studies that applied modelling based on accessed transport data), and in some cases this was complemented with data from travel diaries, walking/cycling datasets, vehicle-based commute data, and/or weather data. Some studies gathered longitudinal data (on an annual basis), but others applied a shorter period of time ranging between 2 months and 12 months. Longitudinal methods were more common among papers evaluating current government or local council initiatives and programmes. Studies based on experimental design and trials tended to have shorter timeframes. The target groups for the intervention also differed from one study to another. A few studies, particularly those looking at information and advice interventions, focused on school-age children. Other specific groups included in some studies were people moving to a new city and residents from areas where specific interventions were implemented (eg, avenues where new or extended cycling and walking infrastructure was built). Other studies did not focus on specific population groups; instead, they focused on city areas where the goal of the intervention was to tackle traffic congestion and/or reduce emissions (eg, congestion charging in Gothenburg or London).

The interventions reported here have been categorised by where they sit in the Waka Kotahi Avoid–Shift–Improve model. Most interventions sat within the Shift aspect of the model where they aimed to reduce LVT by supporting mode shift through incentives, improved infrastructure, and information. Others were a combination of aiming to avoid and/or reduce car trips (eg, through congestion charging and car parking restrictions) as well as supporting alternative modes (eg, improving public transport services). Few studies reported Avoid measures only. Interestingly, Kuss and Nicholas (2022) did not find any effective interventions that only used 'push' approaches, suggesting that 'stick' type approaches seeking to reduce car trips may be most effective when combined with alternative means to travel that act as a 'carrot'. In the Waka Kotahi model, 'Avoid' also includes improvements to accessibility through integrated transport and land use. While we did not find reports of interventions at this scale, observational studies comparing travel patterns between more and less walkable urban form suggest strong causal relationships.

While the range of interventions in this review was comparable with recent systematic reviews, there are likely to be more approaches and techniques for LVT reduction that need to be included. A deeper dive into interventions would benefit starting with a framework or concept of travel change and/or mode shift that then drove a purposeful search for interventions that operationalised change mechanisms. Similarly, a broader systems view would consider how LVT reduction sits within a wider framework of emissions reduction and allow greater consideration of the complexity of interactions with, and implications of, LVT reduction for co-benefits such as wellbeing, productivity and equity.

Despite the variability in reporting, the following insights for achieving LVT reduction in New Zealand emerged from the review.

- There is emerging evidence about the use of *incentives* to reduce car use during rush hours or use alternative modes of transportation (eg, e-bikes). The interventions we have analysed primarily look at financial or material incentives (even though an incentive can be in the form of a positive stimulus/feedback or recognition). While there is limited rigorous evidence of interventions using incentives for traffic reduction/mode shift, research interest in incentives has centred, to some extent, on safe driving. From the evidence it appears that for the implementation of an incentive approach to succeed, it needs to be clear about:
  - the type of incentive being given
  - how long the incentive will last
  - whom the incentive is targeted at
  - the type of behaviour to be changed.
- Incentives appear to be more effective when applied with other approaches. Further consideration could be given to identifying the most impactful combinations. Unsurprisingly, they appear to be most effective in cities with established active and public transport infrastructure, which has implications for their relevance to New Zealand's regional cities and/or those with limited infrastructure. They also appear to have greater impact in contexts where populations have high socio-economic status and living standards, which raises the question of how effective they might be in New Zealand's relatively deprived areas.

  Emerging approaches to incentives in transport science and practice such as gamification are yet to be fully tested and evaluated for LVT reduction and mode shift. The use of gamification in reducing car use/traffic is still incipient but is being used to help new/young drivers improve their driving skills – for example, in New Zealand the GoDrive app uses gamification elements. Note that while gamification heavily relies on IT systems, its core aspect is that it aims to actively engage people in a game-like environment to achieve a desired behavioural change. Gamification has been applied to increase walking trips, but we were not able to find examples targeting other modes. Relevant insights from non-VKT reduction literature include the following.

  - Younger populations are more sensitive to incentives.
  - Effective incentives include material/financial incentives such as insurance premiums and values-based incentives such as peer pressure.
  - Gamification can be effective for safety.
- Research on changing behaviour towards *active travel* is encouraging. The evidence suggests that the implementation of interventions encouraging walking and cycling are overall effective; however, effectiveness of interventions differs depending on the way they are defined and operationalised. Also, it seems that the extent of the impact that active travel interventions will have depends on the existence or implementation of additional complementary activities/services such as availability of walking/cycling infrastructure and information campaigns and resources.
- Evidence shows that when *parking costs* are increased, employees move to active and sustainable modes of transportation. Conversely, when workplace parking costs are relaxed, people tend to use cars more often.
- *Travel plan approaches* have been used with children and their families. Evidence suggests that actively supporting family members to reflect about the use of alternative travel modes is more effective than only delivering information to them.
- Evidence suggests that, overall, the provision of adequate *infrastructure* can increase active travel. The implication is that addressing gaps through basic provision may be more effective than refinement of existing active travel infrastructure.
- *Congestion charging* seems to be a preferred policy approach in different jurisdictions (as it also provides revenues). The extent of impact differs across these jurisdictions due to the nature of the schemes. However, a key lesson is that pricing should be continuously adjusted upwards over time to actively manage demand.

The types of interventions reported have changed over time. Earlier research on reducing LVT was initially interested in interventions looking at approaches such as congestion charges, changing active travel behaviours, and infrastructure development. While these approaches are still the focus of some recent studies, more recent research has incorporated a wider range of incentives and gamification-based approaches as ways to reduce car use.

The map-based dashboard described in chapter 4 provides a visual, interactive means of presenting key features of the reviewed interventions. The interface allows users to identify interventions depending on their interest using the filters; for example, by the type of intervention, location, or level of transferability. Given the general paucity of contextual information provided in most reports, the geographical nature of the dashboard means it is possible to add context through spatial characteristics. We have provided basic climate zones to illustrate the potential for including spatial factors so that, for example, users could consider whether some types of interventions are more common in temperate zones. While this approach holds promise, it is reliant on global measures and datasets being available that provide sufficient granularity to be able to make useful distinctions between New Zealand settlements. We attempted to include population density as a proxy for differences in urban form; however, identifying appropriate and accessible global datasets was a considerably more complicated task than originally anticipated. Other potential contextual factors could be topography and public transport infrastructure maturity. It may be more realistic to consider the incorporation of country-specific datasets as they are available. Consideration would also need to be given to how to ensure useful scales are used so that, for example, Nelson can be compared with Tokyo.

While the focus of this review was on interventions, other studies can also provide insights into the underlying mechanisms behind LVT. The recent shift to WFH has certainly reduced private LVT but was not an intended intervention. While WFH has reduced LVT during the Covid-19 pandemic, it is not evenly

available to all as a viable option. It depends on what people do (Brodeur et al., 2021), as well as who and where they are (Barbour et al., 2021), meaning there is potential for a reliance on WFH to increase inequalities in New Zealand. The pandemic accelerated existing trends in so called 'virtual' participation in work and services. Telemedicine, for example, offers a means of reducing emissions primarily through reduced travel (Purohit et al., 2021). But what about the quality and effectiveness of the services provided? Do they deliver the same or better outcomes as face-to-face service delivery? If the rapid shift towards virtual participation in services is an effective means of reducing LVT, it will require careful evaluation of what services are best delivered remotely, to whom, and when – and conversely, whose outcomes are worsened either through onerous reliance on virtual participation, or because of reduced face-to-face options.

While virtual options are emerging as game changers in reducing LVT, the importance of physical aspects of moving people and goods around remains fundamental. PnR facilities can better connect people to viable public transport alternatives when targeted at reducing longer journeys that would otherwise be car-based (Zijlstra et al., 2015). However, context may be important; less is known about the effectiveness of PnR in areas with less mature transit infrastructure (Haque et al., 2021). Research on the characteristics of accessibility has demonstrated the importance of physical features such as streetscape, the provision of active and public transport infrastructure and services, and density of housing and destinations, and that these destinations contribute to wellbeing (Baum & Palmer, 2002; Witten et al., 2012). The 20-minute city model emphasises the interaction between what is built and the functions they provide for people and communities.

Two overarching lessons emerged from the scan of recent relevant systematic reviews. Firstly, the small number of eligible reports found here is not surprising; all the systematic reviews struggled to find suitable papers, and their qualities varied considerably (Kuss & Nicholas, 2022). Secondly, interventions cannot be considered on their own, either because they are likely to be context dependent or because there is a strong indication that interacting interventions are more effective (Javaid et al., 2020).

8.1 Recommendations for building an evidence database

The findings from this research suggest that the following lessons are relevant when building an evidence base to support the reduction of LVT in New Zealand cities.

How evidence is collated and evaluated

- Develop a mosaic of evidence that represents the diversity of methods required to evaluate the full range of interventions needed to reduce LVT in New Zealand. The mosaic approach to collating evidence and evaluating the effectiveness of interventions needs to incorporate useful, structured methods for classifying and comparing diverse interventions (and purposes) and evaluation types, including factors such as context as well as the internal validity and quality of study design.
- Shift the focus of undertaking and comparing intervention evaluations from hypothesis testing to assessing the functions of an intervention.
- When comparing interventions, consider the purpose: Is the aim for a lot of change for few, or a little change for many?
- Beware of 'effect size' comparisons: Interventions addressing determinants will have smaller effect sizes than targeted interventions but have a greater reach across populations, and therefore impact.
- Interventions that seek to address determinants of behaviour (such as LVT and mode shift) may be best evaluated by considering the findings from multiple studies to come to a 'good enough' conclusion.

How evidence is generated

- Fund and publish evaluations through integration into transport project planning scope and budgets.

- Allow for evaluation data gathering to take place at appropriate time scales (ie, before an intervention starts and after behaviours have adapted to changes).
- Aim for comparability in the measurement and reporting of project evaluations. Comparability and causation are the goals of quality methods and reporting.
- Optimise opportunities arising from real-world natural trials and experiments through staging and comparisons with non-intervention sites.
- Facilitate long-term, evolving evaluations of complex changes likely to affect LVT and mode shift (eg, 20-minute city endeavours).
- Capture information on the context of an intervention to aid comparisons, including geographical, environmental, economic, socio-cultural, and built environment features.
- Recognise that the academic research model can add value to the wider evidence base and support collaborations between researchers and the transport sector (perhaps treating the Te Ara Mura research programme as a case study for identifying lessons).

Further development of the LVT reduction evidence base

- Explore how to integrate intervention evaluations with causal modelling-based assessments.
- Combine and synthesise evidence and intervention types – towards building a mosaic of evidence.
- Explore how the intervention types identified in this study might synergistically interact with each other and the specific context of Tier 1 and 2 urban environments in New Zealand.
- User-test the interactive dashboard to identify the most useful filters and information, including how contextual information could be added through spatially available information.
- Explore how the evidence needs of different users could be met in a mosaic-type evidence base. For example, how could the diversity of evidence be made helpful (rather than a hindrance) in the Environment Court as well as for community engagement?
- The relevance to New Zealand Tier 1 and 2 urban environments ranking was dichotomised as ‘yes’ or ‘no’. A more nuanced ranking could be reached through more in-depth consideration of city characteristics and the relative maturity of non-vehicle transport cultures and infrastructure.

8.2 Limitations

Due to time constrains for this project, we did not undertake a full systematic literature review. While this is a limitation, we are confident on the output of, and lessons from, the narrative review project. When we checked the range of interventions reported in other systematic reviews, we found that our review covered the ground adequately.

Another limitation is that subjectivity in the searching and inclusion process was a possibility. To avoid this, the authors iteratively reviewed the papers and discussed the merits, findings, and applicability of the material identified. This process was supported by the decision-tree framework developed for this project, which outlines the criteria for inclusion and quality.

As this project had a clear focus on effective interventions to reduce LVT relevant to the New Zealand context, it may be that this did not allow for a comprehensive coverage of evidence discussing related issues and/or opportunities. To deal with this, we have included in this report a summary of recent relevant systematic reviews (chapter 6) and commentary on the issues of developing evidence in cases such as this (chapter 7).

9 Conclusion

According to the evidence reported in this narrative review, there are multiple avenues for reducing LVT in New Zealand. They cover interventions seeking to avoid and/or reduce car trips as well as encouraging and enabling people to shift their travel from private vehicles to active and public transport. The literature reviewed in this report suggests that financial and material incentives, parking costs and travel planning all have an important part to play in encouraging mode shift. There is also consistent evidence that providing adequate active transport infrastructure is needed to enable mode shift, which was an important consideration when assessing how transferable interventions would be to New Zealand's Tier 1 and 2 urban environments.

The scale and targets of interventions reviewed varied considerably. Reports on smaller-scale interventions targeted at households and individuals tended to be focused on one or two types of interventions, such as travel planning and/or an incentive delivered over a matter of weeks or months. Relatively bespoke measures such as these may be best delivered at local planning levels to address specific opportunities and needs of communities and transport pressure points. Larger-scale, more complex interventions such as Te Ara Mua – Future Streets, ACTIVE, and the 'mini-Hollands programme' covered wider neighbourhood or suburb areas and included multiple types of interventions (eg, combinations of infrastructure, improvements to public transport, information, travel planning) delivered over years. The intervention evidence literature and wider observational studies suggest these types of complex interventions may be better placed to reduce LVT because they address the underlying determinants of LVT. The level of investment and resources needed to deliver this scale of change is likely to be best delivered at regional (and at times, national) planning levels.

Making meaningful comparisons across the reported interventions was challenging. There is considerable variability in what was reported as well as the quality of study designs, on top of the range of interventions. Recognising the limitations of how evidence is generated and what is needed by decision-makers, a 'mosaic' approach to collating and comparing evidence may better account for the variety of approaches needed to reduce LVT and the types of evaluations reported. Strengthening and expanding the evidence base is important if evidence is to inform decisions about how to invest in LVT reduction in New Zealand. While we do not wish to over-emphasise the importance of the academic model in evidence generation, the current research funding model cannot and should not bear the burden of producing evidence. Better collaboration between researchers and the transport sector offers a way forward for evaluations that are robust and fundable, perhaps using the Te Ara Mura study as a case study.

There were serious gaps in what is reported across studies and therefore what can be inferred for New Zealand. Few reports provided sufficient information to assess the equity impacts of interventions, with little information on the age, ethnicity or socio-economic status of participants or areas. Contextual factors such as population density and the culture and maturity of active and public transport infrastructure were often missing. Mapping studies so that geographical characteristics (such as population density) can be added in as spatial layers may be a useful means of providing the extra contextual information needed to make sense of the evidence base for New Zealand.

Embracing the messiness of evidence (Ogilvie, Bauman, et al., 2020) is challenging but necessary to get the most knowledge and wisdom out of what is available. Overall, there is evidence that interventions addressing the multi-layered, complex determinants of LVT can both help people avoid or reduce car trips as well as shift their travel to alternative available and viable modes.

References

Albris, K., Lauta, K. C., & Raju, E. (2020). Disaster knowledge gaps: Exploring the interface between science and policy for disaster risk reduction in Europe. *International Journal of Disaster Risk Science*, *11*(1), 1–12. https://doi.org/10.1007/s13753-020-00250-5

Aldred, R., Croft, J., & Goodman, A. (2019). Impacts of an active travel intervention with a cycling focus in a suburban context: One-year findings from an evaluation of London's in-progress mini-Hollands programme. *Transportation Research Part A: Policy and Practice*, *123*, 147–169. https://doi.org/10.1016/j.tra.2018.05.018

Baethge, C., Goldbeck-Wood, S., & Mertens, S. (2019). SANRA – a scale for the quality assessment of narrative review articles. *Research Integrity and Peer Review*, *4*(1), 5. https://doi.org/10.1186/s41073-019-0064-8

Bamberg, S. (2006). Is a residential relocation a good opportunity to change people's travel behavior? Results from a theory-driven intervention study. *Environment and Behavior*, *38*(6), 820–840. https://doi.org/10.1177/0013916505285091

Barbour, N., Menon, N., & Mannering, F. (2021). A statistical assessment of work-from-home participation during different stages of the COVID-19 pandemic. *Transportation Research Interdisciplinary Perspectives*, *11*, 100441. https://doi.org/10.1016/j.trip.2021.100441

Baum, F., & Palmer, C. (2002). 'Opportunity structures': Urban landscape, social capital and health promotion in Australia. *Health Promotion International*, *17*(4), 351–361. https://doi.org/10.1093/heapro/17.4.351

Ben-Elia, E., & Ettema, D. (2011). Rewarding rush-hour avoidance: A study of commuters' travel behavior. *Transportation Research Part A: Policy and Practice*, *45*(7), 567–582. https://doi.org/10.1016/j.tra.2011.03.003

Börjesson, M., & Kristoffersson, I. (2015). The Gothenburg congestion charge. Effects, design and politics. *Transportation Research Part A: Policy and Practice*, *75*, 134–146. https://doi.org/10.1016/j.tra.2015.03.011

Brodeur, A., Cook, N., & Wright, T. (2021). On the effects of COVID-19 safer-at-home policies on social distancing, car crashes and pollution. *Journal of Environmental Economics and Management*, *106*, 102427. https://doi.org/10.1016/j.jeem.2021.102427

Cairns, S., Sloman, L., Newson, C., Anable, J., Kirkbride, A., & Goodwin, P. (2008). Smarter choices: Assessing the potential to achieve traffic reduction using 'soft measures'. *Transport Reviews*, *28*(5), 593–618. https://doi.org/10.1080/01441640801892504

Cambra, P., & Moura, F. (2020). How does walkability change relate to walking behavior change? Effects of a street improvement in pedestrian volumes and walking experience. *Journal of Transport & Health*, *16*, 100797. https://doi.org/10.1016/j.jth.2019.100797

Cerin, E., Cain, K. L., Conway, T. L., Dyck, D. V., Hinckson, E., Schipperijn, J., Bourdeaudhuij, I. D., Owen, N., Davey, R. C., Hino, A. A. F., Mitáš, J., Orzanco-Garralda, R., Salvo, D., Sarmiento, O. L., Christiansen, L. B., Macfarlane, D. J., Schofield, G., & Sallis, J. F. (2014). Neighborhood environments and objectively measured physical activity in 11 countries. *Medicine and Science in Sports and Exercise*, *46*(12), 2253–2264. https://doi.org/10.1249/MSS.0000000000000367

Cervero, R., Golub, A., & Nee, B. (2007). City CarShare: Longer-term travel demand and car ownership impacts. *Transportation Research Record*, *1992*(1), 70–80. https://doi.org/10.3141/1992-09

Chapman, R., Keall, M., Howden-Chapman, P., Grams, M., Witten, K., Randal, E., & Woodward, A. (2020). *A cost benefit analysis of an active travel intervention with health and carbon emission reduction benefits*. https://doi.org/10.26686/wgtn.13058594

Dale, S., Frost, M., Ison, S., & Budd, L. (2019). The impact of the Nottingham Workplace Parking Levy on travel to work mode share. *Case Studies on Transport Policy*, *7*(4), 749–760. https://doi.org/10.1016/j.cstp.2019.09.001

de Kruijf, J., Ettema, D., Kamphuis, C. B. M., & Dijst, M. (2018). Evaluation of an incentive program to stimulate the shift from car commuting to e-cycling in the Netherlands. *Journal of Transport & Health*, *10*, 74–83. https://doi.org/10.1016/j.jth.2018.06.003

De Vos, J. (2020). The effect of COVID-19 and subsequent social distancing on travel behavior. *Transportation Research Interdisciplinary Perspectives*, *5*, 100121. https://doi.org/10.1016/j.trip.2020.100121

Eriksson, L., Garvill, J., & Nordlund, A. M. (2008). Interrupting habitual car use: The importance of car habit strength and moral motivation for personal car use reduction. *Transportation Research Part F: Traffic Psychology and Behaviour*, *11*(1), 10–23. https://doi.org/10.1016/j.trf.2007.05.004

Fitz-Walter, Z., Johnson, D., Wyeth, P., Tjondronegoro, D., & Scott-Parker, B. (2017). Driven to drive? Investigating the effect of gamification on learner driver behavior, perceived motivation and user experience. *Computers in Human Behavior*, *71*, 586–595. https://doi.org/10.1016/j.chb.2016.08.050

Frank, L. D., Hong, A., & Ngo, V. D. (2021). Build it and they will cycle: Causal evidence from the downtown Vancouver Comox Greenway. *Transport Policy*, *105*, 1–11. https://doi.org/10.1016/j.tranpol.2021.02.003

Fujii, S., & Kitamura, R. (2003). What does a one-month free bus ticket do to habitual drivers? An experimental analysis of habit and attitude change. *Transportation*, *30*(1), 81–95. https://doi.org/10.1023/A:1021234607980

Fujii, S., & Taniguchi, A. (2005). Reducing family car-use by providing travel advice or requesting behavioral plans: An experimental analysis of travel feedback programs. *Transportation Research Part D: Transport and Environment*, *10*(5), 385–393. https://doi.org/10.1016/j.trd.2005.04.010

Günther, M., Kacperski, C., & Krems, J. F. (2020). Can electric vehicle drivers be persuaded to eco-drive? A field study of feedback, gamification and financial rewards in Germany. *Energy Research & Social Science*, *63*, 101407. https://doi.org/10.1016/j.erss.2019.101407

Haque, A. M., Rezaei, S., Brakewood, C., & Khojandi, A. (2021). A literature review on park-and-rides. *Journal of Transport and Land Use*, *14*(1), 1039–1060.

Harris, M. A., & Crone, D. (2021). Using gamification to encourage active travel. *Journal of Transport & Health*, *23*, 101275. https://doi.org/10.1016/j.jth.2021.101275

Hensher, D. A., Beck, M. J., & Wei, E. (2021). Working from home and its implications for strategic transport modelling based on the early days of the COVID-19 pandemic. *Transportation Research Part A: Policy and Practice*, *148*, 64–78. https://doi.org/10.1016/j.tra.2021.03.027

Hiselius, L. W., & Rosqvist, L. S. (2016). Mobility Management campaigns as part of the transition towards changing social norms on sustainable travel behavior. *Journal of Cleaner Production*, *123*, 34–41. https://doi.org/10.1016/j.jclepro.2015.08.055

Hosking, J., Mackie, H., Macmillan, A., van der Werf, B., Smith, M., Witten, K., & Woodward, A. (2022). *Effects of Te Ara Mua – Future Streets suburban street retrofit on traffic speed and volume: Controlled before-after study* (SSRN Scholarly Paper No. 4120072). Social Science Research Network. https://doi.org/10.2139/ssrn.4120072

Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Mitigation of climate change*. https://www.ipcc.ch/report/ar6/wg3/

Jakobsson, C., Fujii, S., & Gärling, T. (2002). Effects of economic disincentives on private car use. *Transportation*, *29*(4), 349–370. https://doi.org/10.1023/A:1016334411457

Javaid, A., Creutzig, F., & Bamberg, S. (2020). Determinants of low-carbon transport mode adoption: Systematic review of reviews. *Environmental Research Letters*, *15*(10), 103002. https://doi.org/10.1088/1748-9326/aba032

Johansson, C., Burman, L., & Forsberg, B. (2009). The effects of congestions tax on air quality and health. *Atmospheric Environment*, *43*(31), 4843–4854. https://doi.org/10.1016/j.atmosenv.2008.09.015

Knott, C. S., Sharp, S. J., Mytton, O. T., Ogilvie, D., & Panter, J. (2019). Changes in workplace car parking and commute mode: A natural experimental study. *Journal of Epidemiology and Community Health*, *73*(1), 42–49. https://doi.org/10.1136/jech-2018-210983

Kuss, P., & Nicholas, K. A. (2022). A dozen effective interventions to reduce car use in European cities: Lessons learned from a meta-analysis and Transition Management. *Case Studies on Transport Policy*, *10*(3), 1494–1513. https://doi.org/10.1016/j.cstp.2022.02.001

Metz, D. (2018). Tackling urban traffic congestion: The experience of London, Stockholm and Singapore. *Case Studies on Transport Policy*, *6*(4), 494–498. https://doi.org/10.1016/j.cstp.2018.06.002

Ministry for the Environment. (2022). *Te hau mārohi ki anamata: Towards a productive, sustainable and inclusive economy. Aotearoa New Zealand's first emissions reduction plan.* https://environment.govt.nz/assets/publications/Aotearoa-New-Zealands-first-emissions-reduction-plan.pdf

Ministry of Transport. (2020). *The congestion question. Could road pricing improve Auckland's traffic?* https://www.transport.govt.nz/assets/Uploads/Report/The-Congestion-Question-Report.pdf

Mölenberg, F. J. M., Panter, J., Burdorf, A., & van Lenthe, F. J. (2019). A systematic review of the effect of infrastructural interventions to promote cycling: Strengthening causal inference from observational data. *International Journal of Behavioral Nutrition and Physical Activity*, *16*(1), 93. https://doi.org/10.1186/s12966-019-0850-1

Nacke, L. E., & Deterding, S. (2017). The maturing of gamification research. *Computers in Human Behavior*, *71*, 450–454. https://doi.org/10.1016/j.chb.2016.11.062

Ogilvie, D., Adams, J., Bauman, A., Gregg, E. W., Panter, J., Siegel, K. R., Wareham, N. J., & White, M. (2020). Using natural experimental studies to guide public health action: Turning the evidence-based medicine paradigm on its head. *Journal of Epidemiology and Community Health*, *74*(2), 203–208. https://doi.org/10.1136/jech-2019-213085

Ogilvie, D., Bauman, A., Foley, L., Guell, C., Humphreys, D., & Panter, J. (2020). Making sense of the evidence in population health intervention research: Building a dry stone wall. *BMJ Global Health*, *5*(12), e004017. https://doi.org/10.1136/bmjgh-2020-004017

Panter, J., Guell, C., Humphreys, D., & Ogilvie, D. (2019). Can changing the physical environment promote walking and cycling? A systematic review of what works and how. *Health & Place*, *58*, 102161. https://doi.org/10.1016/j.healthplace.2019.102161

Paré, G., & Kitsiou, S. (2017). Chapter 9: Methods for literature reviews. In F. Lau & C. Kuziemsky (Eds.), *Handbook of eHealth evaluation: An evidence-based approach* [Internet]. University of Victoria. https://www.ncbi.nlm.nih.gov/books/NBK481583/

Patterson, R., Ogilvie, D., & Panter, J. (2020). The social and physical workplace environment and commute mode: A natural experimental study. *Preventive Medicine Reports*, *20*, 101260. https://doi.org/10.1016/j.pmedr.2020.101260

Purohit, A., Smith, J., & Hibble, A. (2021). Does telemedicine reduce the carbon footprint of healthcare? A systematic review. *Future Healthcare Journal*, *8*(1), e85–e91. https://doi.org/10.7861/fhj.2020-0080

Rodríguez, M. D., Roa, R. R., Ibarra, J. E., & Curlango, C. M. (2014). In-car ambient displays for safety driving gamification. In *Proceedings of the 5th Mexican Conference on Human-Computer Interaction* (pp. 26–29). Association for Computing Machinery. https://doi.org/10.1145/2676690.2676701

Semenescu, A., Gavreliuc, A., & Sârbescu, P. (2020). 30 years of soft interventions to reduce car use – A systematic review and meta-analysis. *Transportation Research Part D: Transport and Environment*, *85*, 102397. https://doi.org/10.1016/j.trd.2020.102397

Sezgin, E., & Lin, S. (2019). Technology-based interventions, assessments, and solutions for safe driving training for adolescents: Rapid review. *JMIR MHealth and UHealth*, *7*(1), e11942. https://doi.org/10.2196/11942

Smith, M., Hosking, J., Woodward, A., Witten, K., MacMillan, A., Field, A., Baas, P., & Mackie, H. (2017). Systematic literature review of built environment effects on physical activity and active transport – an update and new findings on health equity. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 158. https://doi.org/10.1186/s12966-017-0613-9

Song, Y., Preston, J., & Ogilvie, D. (2017). New walking and cycling infrastructure and modal shift in the UK: A quasi-experimental panel study. *Transportation Research Part A: Policy and Practice*, *95*, 320–333. https://doi.org/10.1016/j.tra.2016.11.017

Stappers, N. E. H., Van Kann, D. H. H., Ettema, D., De Vries, N. K., & Kremers, S. P. J. (2018). The effect of infrastructural changes in the built environment on physical activity, active transportation and sedentary behavior – A systematic review. *Health & Place*, *53*, 135–149. https://doi.org/10.1016/j.healthplace.2018.08.002

Stappers, N. E. H., Van Kann, D. H. H., Jansen, M. W. J., Kremers, S. P. J., De Vries, N. K., & Bekker, M. P. M. (2020). The role of context in evaluation studies: Lessons from a process evaluation of integrating health in urban reconstruction. *Environmental Impact Assessment Review*, *82*, 106365. https://doi.org/10.1016/j.eiar.2020.106365

Stark, J., Berger, W. J., & Hössinger, R. (2018). The effectiveness of an intervention to promote active travel modes in early adolescence. *Transportation Research Part F: Traffic Psychology and Behaviour*, *55*, 389–402. https://doi.org/10.1016/j.trf.2018.03.017

Steinberger, F., Schroeter, R., & Watling, C. N. (2017). From road distraction to safe driving: Evaluating the effects of boredom and gamification on driving behaviour, physiological arousal, and subjective experience. *Computers in Human Behavior*, *75*, 714–726. https://doi.org/10.1016/j.chb.2017.06.019

Stumpel-Vos, P., Oostrom, C., & van den Berg, V. (2013). *Focus measure evaluation results: UTR 4.1 Mobility management policy*. CIVITAS MIMOSA. https://civitas.eu/sites/default/files/measure_evaluation_results_4_1_mobility_management_policy.pdf

Tannahill, A. (2008). Beyond evidence – to ethics: A decision-making framework for health promotion, public health and health improvement. *Health Promotion International*, *23*(4), 380–390. https://doi.org/10.1093/heapro/dan032

Te Ara Mua – Future Streets. (n.d.). *What were the changes?* https://www.futurestreets.org.nz/what-were-the-changes-before-after/

Thomas, J., Malcolm, L., & Pacheco, E. (2022). *Incentives to encourage safer driving behaviour* (Waka Kotahi NZ Transport Agency research report 706). https://www.nzta.govt.nz/resources/research/reports/706/

Thorwaldson, L., Thomas, F., & Carran-Fletcher, A. (2021). *Evaluating the greenhouse gas emission reduction benefits from land transport mode shift programmes and projects* (Waka Kotahi NZ Transport Agency research note 004). https://www.nzta.govt.nz/assets/resources/research/research-notes/004/004-evaluating-ghg-emission-reduction-benefits.pdf

Waka Kotahi NZ Transport Agency. (2020). *Whakarāpopoto a Aotearoa: National summary*. https://www.nzta.govt.nz/assets/planning-and-investment/arataki/docs/national-summary-august-2020.pdf

Wen, L. M., Fry, D., Merom, D., Rissel, C., Dirkis, H., & Balafas, A. (2008). Increasing active travel to school: Are we on the right track? A cluster randomised controlled trial from Sydney, Australia. *Preventive Medicine*, *47*(6), 612–618. https://doi.org/10.1016/j.ypmed.2008.09.002

Wimbadi, R. W., Djalante, R., & Mori, A. (2021). Urban experiments with public transport for low carbon mobility transitions in cities: A systematic literature review (1990–2020). *Sustainable Cities and Society*, *72*, 103023. https://doi.org/10.1016/j.scs.2021.103023

Witten, K., Blakely, T., Bagheri, N., Badland, H., Ivory, V. C., Pearce, J., Mavoa, S., Hinckson, E., & Schofield, G. (2012). Neighborhood built environment and transport and leisure physical activity: Findings using objective exposure and outcome measures in New Zealand. *Environmental Health Perspectives*, *120*(7), 971–977. https://doi.org/10.1289/ehp.1104584

World Health Organization. (2019). *WHO guideline: Recommendations on digital interventions for health system strengthening*. https://apps.who.int/iris/handle/10665/311941

Zijlstra, T., Vanoutrive, T., & Verhetsel, A. (2015). A meta-analysis of the effectiveness of park-and-ride facilities. *European Journal of Transport and Infrastructure Research*, *15*(4). https://doi.org/10.18757/ejtir.2015.15.4.3099