Assessing the relationship between the sustainability of urban form and transport in Aotearoa New Zealand

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C Lee, Beca, Wellington
V Li, Beca, Auckland
K Stringer, Beca, Wellington
D Goodall, Beca, Auckland
A Wingham, Beca, Auckland
J Hafoka, Beca, Auckland
M Sharp, Beca, Auckland
M Te Tana, Beca, Wellington
J Khoo, Beca, Auckland

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NZ Transport Agency Waka Kotahi
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

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This research was conducted under a previous policy context. For example, the research was developed and/or undertaken under the 2021-24 Government Policy Statement for Land Transport. Consequently, references contained in the report may be to policies, legislation and initiatives that have been concluded and/or repealed. Please consider this in your reading of the report and apply your judgement of the applicability of the findings to the current policy context accordingly.

[1] This research was conducted July 2022-September 2023.

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Abbreviations and acronyms

CBD	central business district
COVID-19	coronavirus disease 2019 (SARS-CoV-2) and associated pandemic
GHG	greenhouse gas
GP	general practitioner (local doctor)
LGBTTQI+	umbrella term for lesbian, gay, bisexual, transgender, takatāpui, queer and intersex people
MCP	Model Communities Programme
MDRS	Medium Density Residential Standards 2022
NPS-UD	National Policy Statement on Urban Development 2020
NZTA	NZ Transport Agency Waka Kotahi
ONRC	One Network Road Classification
RAMM	road assessment and maintenance management
RLC FDS	Rotorua Lakes Council Future Development Strategy
RMA	Resource Management Act 1991
PEET	Project Emissions Estimation Tool
TAZ	traffic analysis zone
VEPM	Vehicle Emissions Prediction Model
VKT	vehicle kilometres travelled

Contents

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Executive summary

Integrated transport and land-use planning is recognised as important in creating an urban environment that achieves broader social, economic and environmental outcomes. While international studies have demonstrated these benefits, the necessary pre-conditions required to achieve them in Aotearoa New Zealand are not well understood.

The research was carried out for NZ Transport Agency Waka Kotahi (NZTA) between July 2022 and September 2023 with the aim to address this knowledge gap and enhance understanding of the relationship between the sustainability of urban form and transport in New Zealand. The methods used to achieve this were:

- a literature review of the impacts of different types and mixes of urban form and transport on sustainability and on New Zealand's other core transport outcomes
- eight targeted interviews with key stakeholders and practitioners involved in integrated transport and land-use planning in New Zealand
- 135 digital 'conversations' with the general public about the barriers and opportunities to achieving sustainable transport outcomes through integrated transport and land-use planning using FranklyAI (a conversational tool that utilises artificial intelligence to gather opinions and feedback)
- exploring a methodology and concept design for a tool that can quantify the relationship between transport emissions and regional spatial plans/changes in urban form at a regional scale.

The results of this research are summarised below.

An important note about the findings

A key finding of this research is the need for a systems approach to integrated transport and land-use planning. Therefore, the themes, pre-conditions and subsequent recommendations summarised below must not be considered in isolation as there are many interdependencies and synergies between them.

The recommendations have been developed to help guide and inspire transport agencies (NZTA and local government planners and funders) to develop and define their role in integrated transport and land-use planning. However, individual transport agencies do not have all the levers to achieve the pre-conditions identified in this research. This further highlights the need for a coordinated and collaborative systems approach to transport and land-use integration.

Another key finding is the need for a nuanced and place-based approach to integrated transport and land-use planning that recognises the unique characteristics, challenges and opportunities of places and projects. This requires meaningful engagement with mana whenua, local practitioners and communities (listening, learning and taking their knowledge and experiences into account).

Review of the effectiveness of spatial planning

Taken together, the literature review, interviews and FranklyAI conversations suggest that spatial planning and changes in urban form are an effective method for achieving sustainable transport outcomes in New Zealand when combined with public transport and attractive active mode environments that are matched to the form of development to reduce vehicle kilometres travelled.

In particular, the FranklyAI conversations identified a number of barriers to mode shift (from private vehicles to sustainable transportation) regardless of how well integrated transport is with housing and urban development, which highlights the importance of other factors or pre-conditions to shift people's travel behaviour and realise wider benefits.

Pre-conditions

Drawing from the literature review, interviews with key stakeholders and FranklyAI conversations, we identified some of the necessary pre-conditions for integrated planning of transport and urban form in New Zealand to achieve sustainable transport outcomes. They are hypothesised based on international studies and New Zealand's unique characteristics and socio-economic context. Therefore, they are indicative and require further investigation and testing. The pre-conditions are organised under four key themes, summarised in the table below.

Summary of pre-conditions

Theme	Pre-conditions
Transport infrastructure, services, attitudes and preferences	• There is access to a range of viable sustainable transport options for peoples' travel needs (public transport, walking and cycling) regardless of their social identity and where they live, work, learn and play. • Public transport services need to be reliable, efficient, affordable and safe regardless of trip origin and destination. • Footpaths, walkways and cycleways must provide safe, efficient journeys for people of all ages and abilities to enjoy. • Transport infrastructure and services meet the unique needs of the cities, towns and communities that they serve.
Housing market, attitudes and preferences	• The housing market delivers a range of housing typologies at a range of price points in locations that are well serviced by viable, sustainable transport options, social infrastructure and local amenities. • The housing market effectively meets the housing requirements of Māori by addressing their specific needs, aspirations and cultural preferences. This includes supporting papakāinga and embracing values such as rangatiratanga, kaitiakitanga and mana. • High-density and medium-density housing is high quality and meets the diverse needs of New Zealand's population, communities and households. • A range of people and households desire to live in high-density and medium-density housing because of its quality, amenity and lifestyle offering.
Social infrastructure and local amenities	• People can easily access social infrastructure and local amenities via public transport, walking or cycling regardless of their social identity and where they live, work, learn and play.
Legislation, regulations, funding and operations	• Local planning and regulation enables integration of transport and urban form. • Roads are improved for sustainable transport as part of road maintenance and renewals. • Funding frameworks recognise and value the broad benefits of urban integration. • Urban integration outcomes are carried through the life cycle of projects.

Recommendations

We have explored the greater role that transport agencies (NZTA and local government planners and funders) could play in achieving the necessary pre-conditions for integrated planning of transport and urban form in New Zealand to achieve sustainable transport outcomes. We have made a series of high-level recommendations on next steps for transport agencies to help inspire and guide their thinking. Clearly defining individual transport agencies' roles in integrated transport and land-use planning will help them to identify and prioritise areas for further investigation and/or improvement. To assist with this process, we have identified four key action areas:

- **Influence:** NZTA and local government have the advantage of having many interfaces with the public and private sectors and communities that could be leveraged to influence the system and cultural/behavioural changes needed to achieve the pre-conditions identified in this research. NZTA and local government could play a larger role in educating, advocating and promoting the success of integrated transport and land-use projects to the general public.

- **Facilitation:** NZTA and local government could facilitate some of the pre-conditions identified in this research through their regulatory and operational functions by making it easier and/or more viable for transport and land-use integration projects to reduce transport emissions and achieve broader sustainability outcomes.
- **Leadership:** NZTA and local government are system leaders for transport. Therefore, many organisations (both public and private) look to these transport agencies for guidance on how to execute transport projects. This presents many opportunities for transport agencies to model the behaviours, principles and processes necessary for transport and land-use integration projects to reduce transport emissions and achieve broader sustainability outcomes.
- **Collaboration:** The nature of the work of NZTA and local government means they have many opportunities to partner and collaborate with mana whenua, businesses, local authorities, communities and other central government agencies. Working together will be critical to achieving the system and cultural/behavioural changes that are necessary for transport and land-use integration projects to reduce transport emissions and achieve broader sustainability outcomes.

These action areas and recommendations have been developed for consideration by NZTA and local government as they have specific responsibilities for transport planning and funding. However, some may also be applicable and/or provide inspiration for other national and local planning organisations.

Abstract

Integrated transport and land-use planning is recognised as important in creating an urban environment that achieves broader social, economic and environmental outcomes. While international studies have demonstrated these benefits, the necessary pre-conditions required to achieve them in Aotearoa New Zealand are not well understood. This research aims to address this knowledge gap and enhance the industry's understanding of the relationship between the sustainability of urban form and transport in New Zealand. Research methods used include:

- a literature review of the impacts of urban form on transport outcomes
- eight targeted interviews with key stakeholders and practitioners involved in integrated transport and land-use planning in New Zealand
- 135 online FranklyAI conversations with the general public about their housing and transport preferences
- exploring a methodology and concept design for a tool that can quantify the relationship between transport emissions and regional spatial plans/changes in urban form.

We found that integrated transport and land-use planning is likely to have the greatest impact on transport emissions reductions and other sustainable transport outcomes in New Zealand when combined with comprehensive public transport systems and attractive active mode environments to reduce vehicle kilometres travelled. We also identified the importance of a coordinated, systems and place-based approach to integrated transport and land-use planning in New Zealand that acknowledges the unique characteristics and challenges of places. The identified pre-conditions for successful transport and land-use integration in New Zealand relate to four interconnected themes:

- Transport infrastructure, services, attitudes and preferences.
- Housing market, attitudes and preferences.
- Social infrastructure and local amenities.
- Legislation, regulations, funding and operations.

These pre-conditions are indicative and require further investigation and testing.

Based on the findings of this research, we made a number of high-level recommendations on next steps for transport agencies (NZTA and local government planners and funders) to help achieve the pre-conditions required for successful integrated planning of transport and urban form in New Zealand. These are organised under four key action areas intended to help guide and inspire transport agencies to define and develop their role in integrated transport and land-use planning – influence, leadership, collaboration and facilitation.

We acknowledge that NZTA and local government do not have the levers to directly influence a lot of the pre-conditions identified in this research. However, to create change, they can indirectly influence a lot of the pre-conditions through the levers of advocacy, leadership and working with other public sector agencies such as Kāinga Ora and neighbouring local authorities. NZTA and local government can also seek to improve the existing systems and frameworks that they work within and investigate the identified pre-conditions further through additional research.

1 Introduction

Historically, transport planning in Aotearoa New Zealand has focused on the movement of motorised transportation (particularly the privately owned automobile) from A to B, with limited consideration of surrounding land uses. Rising prosperity in the mid-1900s in New Zealand combined with the emergence of private vehicles led to a dramatic rise in car ownership and use and the construction of arterial road networks to carry them (Department of Internal Affairs, 2008). This paper found that, while suburbs were initially based on public transport systems designed to cater for local community services and amenities, these local businesses and services gradually became less viable as private mobility increased and enabled larger-scale community and retail facilities such as supermarkets to service a much wider catchment than an individual suburb. This has led to a predominantly low-density, dispersed urban form in New Zealand whereby new car-oriented subdivisions typically only contain residential land uses. Today, people in New Zealand predominantly rely on motorised transport to access people, goods and services, with light vehicles accounting for 67% of New Zealand's transport emissions (Ministry of Transport, 2021b).

Both the Climate Change Commission He Pou a Rangi (2021) and Ministry of Transport Te Manatū Waka (2021b) have identified the need for integrated transport and land-use planning to reduce transport emissions and provide wider benefits such as maintaining/improving access in growing cities. Integrated transport and land-use planning recognises that transport is about both the movement and access of people and goods, and in doing so, it seeks to shape better-functioning urban environments that enable people to change their travel behaviour in favour of more sustainable modes. This is fundamental to reducing transport emissions and creating an urban environment that achieves broad social, economic and environmental outcomes. Without a focus on access, transport planning can increase barriers to social and economic opportunities and create conflicts with the spaces where we live, work and play (such as through traffic congestion, noise and community segregation). Integrated transport and land-use planning therefore requires an expansion of thinking of transport only as corridors for the movement of vehicles to important public spaces that enable people to interact with each other and the natural and built environments in which they live.

While international studies have demonstrated the benefits of integrated transport and land-use planning, the necessary pre-conditions required to achieve them in New Zealand are not well understood. The purpose of this research is to address this knowledge gap by:

- documenting the evidence on the emissions impacts of different urban form typologies and transport in the face of New Zealand socio-economic and cultural preferences (recognising that preferences may be influenced by the market and vice versa or by other elements such as policy settings or environmental factors)
- documenting the necessary pre-conditions that are required to reduce emissions through integrated planning of transport and urban form and any conditions that may have adverse impacts to mitigate/address
- exploring a methodology and concept design for a tool that can quantify the relationship between transport emissions and regional spatial plans/changes in urban form.

A literature review was carried out to understand the emissions impacts of different urban form typologies in New Zealand in the face of New Zealand's socio-economic and cultural preferences. To test and supplement these findings, eight interviews were carried out with key stakeholders and practitioners involved in integrated transport and land-use planning in New Zealand alongside a survey of the general public to better understand the barriers and opportunities to achieving sustainable transport outcomes through urban integration.

Using these findings, a review of the effectiveness of spatial planning or change in land use as an intervention for sustainable mobility in New Zealand was undertaken, the necessary pre-conditions to reduce emissions through integrated planning of transport and urban form were identified and recommendations for transport agencies (NZTA and local government planners and funders) were made on this basis.

This research also explored a methodology and concept design for a tool that can quantify the relationship between transport emissions and urban form. This drew upon a tool previously adapted for the Rotorua Lakes Council Future Development Strategy (RLC FDS) as a practical example of a tool in practice. The purpose is to prototype a tool that can be further developed to quantify the emissions impacts of spatial planning/changes in urban form. This could effectively test the emissions impacts of integrated transport and land-use planning decisions.

This research occurred over the period July 2022 to September 2023.

The remainder of this report is structured as follows:

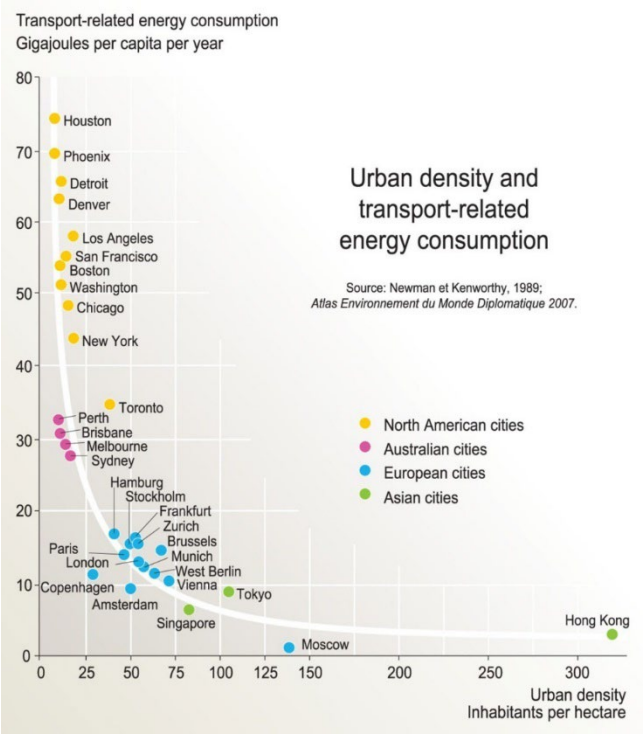
- **2 Background** – provides context to the research, including the key regulatory and policy drivers.
- **3 Methodology** – describes the methods of research that were undertaken.
- **4 Literature review** – provides a summary of the literature review organised thematically.
- **5 Tool development exploration and findings** – describes the process of exploring a methodology and concept design for a tool that can quantify the emissions impacts of spatial planning/changes in urban form and the key findings and recommendations on which the tool development framework is based.
- **6 Review of the effectiveness of spatial planning and initial recommendations on pre-conditions** – reviews the effectiveness of spatial planning and changes in urban form as an intervention for sustainable mobility in New Zealand and identifies the necessary pre-conditions for successful integrated planning of transport and urban form.
- **7 Conclusion and recommendations** – provides recommendations on next steps to help achieve the pre-conditions required for successful integrated planning of transport and urban form in New Zealand.

2 Background

Transport is one of New Zealand's largest sources of greenhouse gas (GHG) emissions, responsible for 17% of gross emissions. According to the Intergovernmental Panel on Climate Change (IPCC, 2018), limiting global warming to 1.5 °C above pre-industrial levels gives us the best chance of avoiding the worst effects of climate change. Thus, urgent action and system-wide changes are needed to put our transport emissions on the trajectory to a low-emissions future. Improving urban form, offering better transport options and using other demand management levers to reduce vehicle kilometres travelled (VKT) by cars is critical to this.

There is a large body of international research that demonstrates the importance of urban form in reducing transport emissions and achieving wider sustainability outcomes. Urban form (shape, size, density and configuration of land uses within a city/town) affects the distances people travel, the frequency at which they travel and the type of mode they choose to travel by, which affects transport emissions. The emissions impact of urban form is demonstrated in Figure 2.1. Both the Climate Change Commission He Pou a Rangi (2021) and the Ministry of Transport Te Manatū Waka (2021b) highlight the need for compact (medium to high density) mixed-use urban form oriented around public transport and active travel networks to reduce reliance on private vehicles and increase opportunities for people to walk, cycle and take public transport. Reducing reliance on private vehicles and enabling more public and active travel is necessary to reduce carbon emissions and achieve wider benefits such as improved safety and access.

Figure 2.1 Urban density and transport-related energy consumption (reprinted from Newman & Kenworthy, 1999)



Urban form can also disproportionately impact people's ability to access desired activities and services. In New Zealand, Māori, Pasifika, disabled people, low-income households, women, older people, children and rural communities are the most likely to experience inequitable access. These groups are also disproportionately represented in related negative impacts such as deaths and serious injuries from transport crashes and illness from transport-related air pollution. To ensure an equitable transition to a low-emissions future, the transport system needs to be more inclusive and affordable.

New Zealand's first emissions reduction plan (Ministry for the Environment, 2022b) contains strategies, policies and actions to contribute to the global effort to limit global warming to 1.5 °C and achieve our first emissions budget, as required by the Climate Change Response Act 2002. The plan outlines the important role that planning and infrastructure have to play in reducing emissions and supporting broader outcomes:

> *Our planning and infrastructure systems influence how and where our towns and cities grow. They shape how decisions are made on the types of infrastructure provided and how infrastructure is funded, financed and used. When infrastructure and planning decisions are made in an integrated way, informed by national objectives, they can help us achieve well-functioning, low emissions urban environments, while enabling us to use our land and resources more carefully and efficiently.* (Ministry for the Environment, 2022b, p. 127)

The plan also highlights the need for integrated land-use planning, urban development and transport planning and investments to enable a variety of mixed-use, medium-density and high-density development in existing urban areas (where social and economic opportunities are greatest) that are well connected to urban centres and active and public transport routes.

While a large body of international research has demonstrated the emissions reduction potential and wider benefits of integrated transport and land-use planning, the necessary pre-conditions required to achieve these outcomes through integrated planning of transport and urban form in New Zealand are not well understood. This is reflected in Action 7.4 of the plan, which is to improve the evidence base and tools for understanding and assessing urban development and infrastructure emissions in New Zealand. This research responds to this research gap by assessing the relationship between the sustainability of urban form and transport in New Zealand and reviewing the effectiveness of spatial planning as a tool to reduce transport emissions.

3 Methodology

The aim of this research was to assess the relationship between the sustainability of urban form and transport in New Zealand.

Specifically, this research set out to:

- document the evidence on the emissions impacts of different urban form typologies and transport in the face of New Zealand socio-economic and cultural preferences (recognising that preferences may be influenced by the market and vice versa or by other elements such as policy settings or environmental factors)
- document the necessary pre-conditions that are required to reduce emissions through integrated planning of transport and urban form and any conditions that may have adverse impacts to mitigate/address
- document the framework for developing a tool that evaluates the transport impacts on emissions arising from the dynamic relationship between different urban forms inside a spatial plan.

To achieve this, we utilised primary and secondary research methods, including a literature review, interviews with key stakeholders and practitioners involved in integrated transport and land-use planning in New Zealand and FranklyAI conversations to enrich these findings with stories and lived experiences. FranklyAI is a conversational agent that utilises artificial intelligence to gather opinions and feedback. More information about FranklyAI is included in section 3.3.

We also explored a methodology and concept design for a tool that can quantify the relationship between transport emissions and spatial planning/changes in urban form. This supported the research objective to document the emissions impacts of different urban form typologies and transport. It also provides a tool development framework to develop a tool in the future that can quantify the emissions impacts of spatial planning/changes in urban form. More information about the tool is included in section 3.4.

3.1 Literature review

The literature review gathered and examined relevant material on the impacts of urban form and transport on sustainability and core transport outcomes in New Zealand. The process followed is outlined below:

- **Scope confirmation:** The scope of the literature review was established by examining factors and conditions related to urban form and transport planning that have social, economic and environmental impacts. This included exploring characteristics of urban form typologies in New Zealand, factors influencing residential typologies, influencing factors on public transport and active travel modes, factors affecting different user groups, and transportation mode choices and related emissions in New Zealand.
- **Identification of credible data sources:** The project steering group helped to identify potential data sources with a focus on publicly available analysis and published academic literature.
- **Searching for relevant material:** The identified data sources were searched for key material relevant to the research topic. We began searching for relevant literature in databases commonly used in urban planning research: Google Scholar, Taylor & Francis Online, JSTOR and Sage Journals. When searching for literature, we used a range of keywords relating to the scope, including ‘transport land-use integration’, ‘urban form’, ‘housing’, ‘density’, ‘housing preferences/aspirations’, ‘urban amenities and density/urban form’, ‘15/20-minute cities’, ‘planning policy’, ‘te ao Māori and housing’, ‘social infrastructure and density/urban form’, ‘equity and urban form/transport’ and ‘transport-related emissions’. Due to the high volume of search results, we focused our attention on sources from New Zealand and limited our search to articles written in English.

- **Literature collation and organisation:** The relevant literature was collected, analysed and organised by theme. Professional judgement was applied to assess the quality of the evidence base, which considered factors such as the number of studies supporting a proposition and the rigour based on peer reviews. Additionally, potential gaps in analysis were identified, which were then explored in the interviews with stakeholders and practitioners.

3.2 Interviews

We undertook eight interviews with key stakeholders and practitioners involved in integrated transport and land-use planning in New Zealand. This included representatives from local and central government, iwi and the private property development industry. Interviews took place online and lasted approximately 1 hour. Interviewees were asked a range of questions broadly relating to:

- urban form
- residential density
- housing preferences
- COVID-19 impacts on housing and transport preferences
- delivering successful integrated transport and land-use planning
- broader outcomes
- property development
- iwi-led development
- papakāinga.

The interviews were semi-structured – while we had a predetermined list of themes and questions to ask at each interview, these were not strictly adhered to. Instead, they were used to facilitate and prompt discussion on the topics of most interest and relevance to the interviewee. For example, interviewees were asked to describe barriers in their area of work (to delivering high density or housing or providing frequent public transport). The intention was to identify systemic issues and interdependencies through further prompts as well as place-based factors. A full list of the pre-determined questions is included as Appendix A.

Notes were taken and circulated to the interviewees shortly following the interview. This gave the interviewees the opportunity to clarify any points and/or add further detail.

3.3 FranklyAI conversations

To enrich the research findings with stories and lived experiences, we utilised FranklyAI, a digital conversational agent powered by generative artificial intelligence that is specifically designed to support natural and engaging conversations, understand customer experiences and gain deeper insights from the community. For a participant or user, chatting with FranklyAI is a lot like talking to a chatbot. However, FranklyAI is more advanced in that it utilises artificial intelligence to redirect questions based on people's answers. It also captures data and analytics such as sentiment.

For this research, FranklyAI's conversational (chatbot) functionality was employed to gather insights, explore different perspectives and develop a better nation-wide understanding of:

- the reasons why people travel in and around their communities
- the factors required to increase uptake of public transport and active modes
- the impacts of different typologies on communities.

First, FranklyAI asked standard demographic questions to determine age, ethnicity, gender and where the participant lived. Then it conducted a theme-focused conversation by asking a leading premise-finder question to identify key words. Depending on the participant's answer to this question, a follow-up set of questions was triggered. The premise-finder questions and their corresponding question sets were grouped into three conversation themes: neighbourhood, housing and transport (Table 3.1). The follow-up question sets were a combination of multi-choice and open text field response questions.

Table 3.1 Example of themes, premise-finder questions and follow-up questions used by FranklyAI

Theme	Premise-finder question	Example follow-up question
Neighbourhood	Tell me what you like about your neighbourhood?	What kinds of amenities do you need nearby to live a good life?
Housing	Tell me about the kind of house you live in? *For example, you could start by describing it as a stand-alone house, an attached unit, a townhouse, a multi-storey apartment building or something else.*	What kind of housing do you most want to live in?
Transport	Tell me about how you usually travel in and around your town/city?	Why do you use the kinds of transport that you do?

Once a question set was completed, FranklyAI would ask the next theme premise-finder question, repeating the same process until all 25 of the prescribed questions had been answered or the respondent had opted out of the conversation. A full list of the questions asked is included as Appendix B.[2]

We conducted approximately 135 online conversations with the public using FranklyAI. These conversations helped to draw out qualitative data and insights that perhaps would not have been shared by participants by engaging in a static set of interview questions.

To disseminate the survey and ensure the response was as representative of New Zealand's population as possible, we used a number of channels and forums such as:

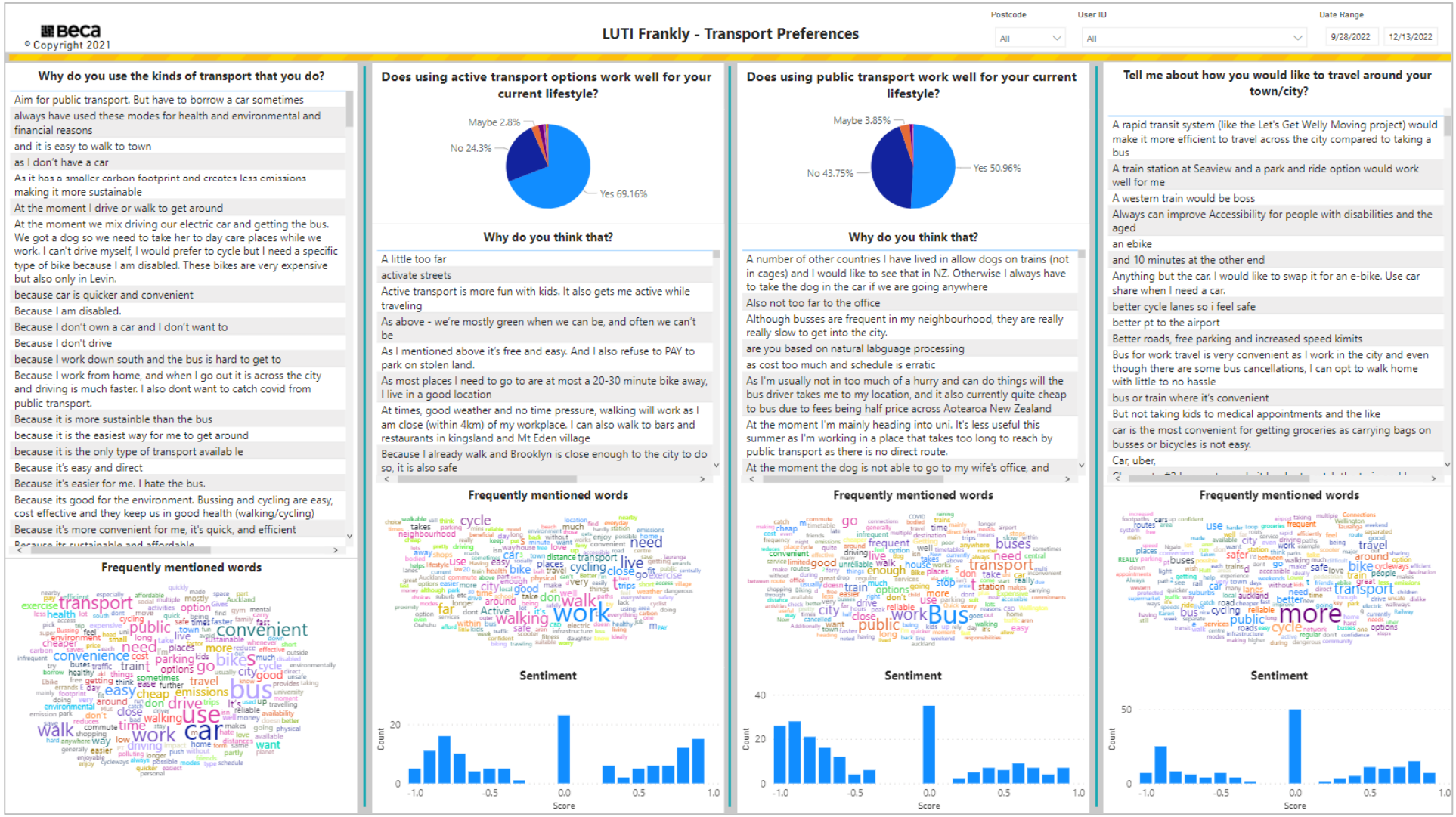
- established connections and relationships with communities and personal contacts
- printed flyers on community noticeboards in Auckland and Wellington (in churches, supermarkets, libraries, universities and playcentres)
- social media promotion (such as on LinkedIn)
- cold calling/emailing community organisations and advocacy groups
- Beca internal communications (such as newsletters).

The views and trends from all respondent conversations were reported and analysed through a dashboard (Figure 3.1). This reporting included analysis of response keywords, respondent sentiment, proportional breakdowns, and demographic and geographic distributions.

Respondents ranged in age from 10 to 77, with the majority of respondents (72%) aged between 18 and 65. Most of the responses were gathered from the three main centres, with Auckland accounting for 43%, Wellington 21% and Christchurch 9%. Additionally, a collective 10% of responses came from Tauranga, Hamilton, Napier, Nelson, Queenstown and Dunedin. Responses were also received from smaller towns such as Morrinsville, Wānaka and Kaiwaka as well as various rural areas.

[2] While participants were asked to describe barriers (a technique that can be ineffective at identifying inter-relationships or sequencing), the intention was to identify systemic issues and interdependencies as well as place-based factors.

Figure 3.1 Snapshot of FranklyAI dashboard



3.4 Tool development framework

To help ascertain the emissions of different urban form typologies and transport, this research explored a methodology and concept design for a tool that can be used to quantify the transport emissions impacts of spatial planning/changes in urban form.

We explored two possible approaches to estimate the high-level emissions impacts of spatial planning/changes in urban form based on land use, demographics and transport supply. The usefulness of each approach hinges on the specific use case (a specific situation in which a product or service could potentially be used). The approaches are:

- for studying individual urban form – a multivariate regression model
- for studying region-wide urban form – a sketch planning tool.

After presenting the advantages and disadvantages of both approaches to the research project steering group (see section 5.1), a sketch planning tool was chosen as the preferred approach to a tool development framework.

Beca previously adapted a multi-modal sketch planning tool for the RLC FDS. This was used to estimate high-level travel demands and the associated emissions by mode in response to different land-use and network assumptions for spatial plans being explored as part of the development of the RLC FDS. With permission from Rotorua Lakes Council, our research focused on the implementation of the sketch planning tool to ascertain the key learnings and opportunities for improvement.

The research also explored the potential to expand the sketch planning tool to estimate the embodied emissions of horizontal infrastructure (footpaths, bus shelters, signage and so on) required to support various urban forms. This utilised the recently completed carbon footprint research from NZTA that assesses the embodied emissions from transport infrastructures (Tapper et al., 2024).

These insights were used to put together a robust set of recommendations upon which we have based the tool development framework provided in Appendix D. The tool development framework can be used by NZTA to develop a similar tool that can quantify the emissions impacts of spatial plans/changes in urban form.

The key learnings and recommendations are summarised in chapter 5 of this report.

4 Literature review

4.1 Key literature review findings

This chapter organises and discusses the literature that was examined by theme. The key findings are summarised below:

- Urban form can be understood as the physical or morphological characteristics of urban spaces. It comprises the spatial distributions of different land uses, physical infrastructure (houses, buildings), density and associated transport networks.
- Sustainable urban form is characterised by compactness, mixed land uses, interconnected street layouts, proximity to transportation nodes and accessible green spaces. When developed in conjunction, these elements reduce VKT and achieve broader social, economic and environmental outcomes.
- The literature on New Zealand's urban form primarily focuses on housing, and there are limited sources regarding other aspects of urban form such as layout and land-use mix. Urban form in New Zealand has historically been characterised as low density. However, research suggests our cities are becoming denser, with the proportion of two-storey dwellings increasing, site sizes decreasing and the number of attached homes increasing.
- This densification has in part been facilitated by the recent introduction of policies such as the National Policy Statement on Urban Development 2020 (NPS-UD)[3] and the Medium Density Residential Standards (MDRS),[4] which have required councils to enable higher levels of urban intensification.
- While there has been an observed shift in density, much of the literature considers urban sprawl to be the prevailing built environment form for much of New Zealand's urban areas, with population growth having been primarily absorbed by greenfield development in recent decades.
- In addition to regulatory and market factors, the literature identifies the desire for detached housing as a contributing factor to urban sprawl in New Zealand. New Zealanders have a strong preference for stand-alone, detached dwellings. This appears to be largely driven by transport and lifestyle choices.
- In saying this, the literature indicates there is an unmet demand for accessible, medium-density housing, with some households willing to trade off dwelling size and neighbourhood type for higher accessibility or lower house prices. The case study of Hobsonville Point (see section 4.4.2) demonstrates that satisfaction with medium-density living is highly influenced by the quality of the public realm, neighbourhood design and access to green spaces.
- Māori and Iwi Housing Innovation (MAIHI) Ka Ora: The National Māori Housing Strategy (Ministry of Housing and Urban Development, 2022) represents the aspirations of Māori for improved housing outcomes for future generations and their whānau over the next 30 years. While Māori are not a homogeneous group and housing aspirations are likely to vary depending on the individual, whānau, hapū or iwi, it is understood that Māori broadly want to create spaces for Māori to be proudly Māori, to be major stakeholders and collective owners of land and, importantly, to be prosperous and comfortable urban residents with mana.
- Spatial planning is seen as an effective tool to plan and coordinate infrastructure. However, a body of international research suggests that spatial planning alone will not result in a sustainable urban form. Rather, an integrated approach to spatial and transport planning processes is needed.

[3] https://environment.govt.nz/assets/publications/National-Policy-Statement-Urban-Development-2020-11May2022-v2.pdf

[4] https://environment.govt.nz/publications/medium-density-residential-standards-a-guide-for-territorial-authorities

- A large number of studies explore the relationship between urban form and enabled transport emissions. There is limited evidence in the literature that captures both the enabled and embodied emissions of urban form characteristics, which further highlights the knowledge gap this research seeks to address.
- VKT reduction is the most prominent theme in the literature in relation to emissions reduction through urban form. Meaningful emissions reductions are achieved when people are enabled to take shorter and fewer private vehicle trips.
- Individual land use characteristics (density, mix, centricity and so on) have minor to moderate impacts on VKT. However, these are synergistic and cumulative, which demonstrates the need to develop these characteristics simultaneously to achieve significant emissions reductions. The literature also argues the need for land-use characteristics to be combined with comprehensive public transport systems and attractive active mode environments to reduce VKT.
- New Zealand's high rates of private vehicle ownership and use mean that mode shift from cars to public transport and active modes and reductions in VKT have the most potential to reduce transport emissions through integrated transport and land-use planning.
- A number of factors affect uptake of active modes – notably attitudes and perceptions, active mode infrastructure (quality, safety, permeability), trip distance and trip time. Research suggests that a combination of infrastructure improvements and education is effective in encouraging a mode shift towards active modes in New Zealand.
- The propensity of students to make school trips by active modes is particularly well researched, with distance found to be the strongest predictor of active travel to school.
- Similar to active modes, attitudes and perceptions are a significant factor in the usage of public transport. Factors such as safety, information, reliability, frequency and travel time all influence a user's confidence and perceived trip difficulty. Mode competitiveness (with private car travel) is also a key factor in public transport uptake.
- There is a body of literature that warns of the potential for transport decarbonisation goals (VKT reduction in particular) to further embed existing transport disadvantage and equity. There are often overlapping aspects of a person's identity that compound barriers to transport. This requires an intersectional approach to transport provision that recognises that barriers to transport are not homogeneous.

4.2 Urban form

The literature on urban form examines key aspects such as density, land use and housing/building type. There are also a vast number of studies that discuss the benefits of sustainable urban form typologies such as 20-minute cities and polycentricity.

4.2.1 Defining urban form and density

To understand how urban form impacts transport emissions, this research first explores the literature on urban form more generally. The literature describes urban form as the physical characteristics of urban spaces and built form and that urban form encompasses both small scale (building, street, block) and large scale (neighbourhood, city, region) and includes the morphological attributes of an area (Williams, 2014; Dempsey et al., 2010). Ghosh and Vale (2009, p. 507) indicate that urban form includes infrastructure and transport networks, stating that it comprises 'spatial distributions of different land uses connected together with physical infrastructures and associated transport networks'. Dempsey et al. (2010) note several elements that make up urban form, including density, housing/building type and land use.

4.2.2 Density

Density typically refers to the number of dwellings, jobs or people per given area (Litman, 2024). Several methods have been used to measure density such as persons per hectare, dwellings per hectare, habitable rooms per hectare, land-use intensity and building coverage (Dempsey et al., 2010; Pont & Haupt, 2007). Density is not a value-free concept. It is inherently ideological, with its desirability highly dependent on context and culture (Dempsey et al., 2010; McFarlane, 2016). Furthermore, there are differences in how density is defined in different contexts. For example, in the United Kingdom, 30 dwellings per hectare is considered higher density, whereas in Hong Kong, 300 dwellings per hectare would not be considered particularly high in terms of density (Dempsey et al., 2010). Perceptions of high, medium and low density in New Zealand are different from these international understandings of density. Historically, the most common urban form in New Zealand is low density, low rise and often rural in character (Ghosh & Vale, 2009). Definitions of density levels in New Zealand include dwelling per hectare ranges but are more commonly based on building typologies. The definition BRANZ gives for medium-density housing is 'multi-unit dwellings (up to 6 storeys)', with low density defined as detached 1–2 storey houses and high density defined as buildings 'greater than 6 storeys' (Bryson & Allen, 2017). The German Advisory Council on Global Change suggests specific guidelines for sustainable cities such as population density of 150 people per hectare, non-residential activities occupying 40% of ground floor space, dedicating 30% of land for roads/traffic infrastructure and ensuring bicycle and pedestrian-friendly environments (Holmes, 2017).

4.2.3 Housing/building type

Buildings and houses can vary greatly in typology, purpose and design. Common examples of housing types include detached housing, semi-detached housing, terraced housing and apartments (Figure 4.1).

Figure 4.1 Housing typologies

Detached housing

Semi-detached housing

Terraced housing

Apartments

Housing types can influence the configuration of the social environment and interactions within residential neighbourhoods (Dempsey et al., 2010). For example, people living in low-density detached dwellings tend to have a distinct experience compared to residents in high-rise apartment buildings. New Zealand's housing is generally single, detached dwellings. However, this is shifting towards more multi-unit developments (Bryson & Allen, 2017), discussed in more detail in section 4.3.2.

4.2.4 Land use

Generally, land use describes the function of the environment. Land-use patterns are typically considered a crucial component of sustainable urban form and can influence travel patterns and the quality of urban life (Dempsey et al., 2010). Layout (not to be confused with land-use mix) includes the spatial arrangements of buildings, streets and blocks. The legibility and permeability of urban layout can determine how well used space is, noting that well-connected communities are more likely to generate movement and activity (Dempsey et al., 2010) (refer to section 4.8.1.4 for commentary on pedestrian permeability). According to Litman (2024), land-use mix is when different types of land use (residential, commercial, institutional, recreational) are located close together. Land-use mix can occur at a small scale (building, apartment or street) or a larger scale (neighbourhood). In the past, planners typically separated land uses. However, mixed-use zoning is becoming more widely used – while there is no consensus in the literature on what specific amenities and facilities should be in neighbourhoods, Dempsey et al. (2010) suggest that a well-functioning neighbourhood typically includes a supermarket, a primary school, a doctor's surgery and a community centre as key components.

4.2.5 Sustainable urban form

Sustainable urban form is characterised by compactness, mixed land uses, interconnected street layouts, proximity to transportation nodes and accessible green spaces (Bibri et al., 2020). These elements support economic, environmental and social sustainability by reducing travel distances, energy consumption per capita and material consumption and by preserving green spaces while facilitating social interactions among diverse groups. According to Williams et al. (2000), sustainable urban form is characterised by compactness, a mix of uses, interconnected street layouts, high standards of urban management, environmental control, proximity to transport nodes and a robust public transport system. Green space is also considered a key element of compact, sustainable urban form. Together, these elements support economic, environmental and social sustainability by reducing travel/commuting and car dependency, lowering energy use per capita, limiting the consumption of construction/infrastructure materials and loss of green space, and encouraging social mixing (Bibri et al., 2020). Compact urban form encourages and facilitates social interactions between people from different social and cultural groups, which can positively influence social cohesion, health outcomes, resource efficiency and cultural dynamics.

4.2.5.1 Compact urban form

Numerous international studies (Cervero & Radisch, 1996; Ewing & Cervero, 2010; Kusumastuti & Nicholson, 2016) have shown the environmental and social benefits of compact urban form, including reduced car dependency, shorter trip lengths and increased use of walking, cycling and public transport. It is widely accepted that compact cities contribute to better health outcomes, social inclusivity, energy efficiency and economic productivity. Enabling compact urban form requires the implementation of policies such as mixed-use zoning, significant investment into mode shift, focusing on brownfield development over greenfield expansion and promoting inner-city living (Holmes, 2017).

4.2.5.2 20-minute city model

The 20-minute city model has gained popularity and offers an example of sustainable urban form. It emphasises easy access to amenities within a 20-minute walk, cycle or public transport journey from home. Moreno et al. (2021) note that access to six essential social functions (living, working, commerce, healthcare, education, entertainment) are required to enable 20-minute cities. The model supports reductions in VKT and the uptake of more sustainable forms of transport by bringing activities, services and amenities closer to neighbourhoods/people (Mackness et al., 2021). This approach supports sustainable transport, reduces congestion and pollution, enhances quality of life and promotes local economic development.

4.2.5.3 Polycentricity

Polycentricity is a type of urban structure that has gained prominence and is characterised by multiple centres or nodes of activity such as employment and commerce that create a network of key hubs within a city (Huai et al., 2021). In contrast, a monocentric city centralises commercial and employment uses in the central business district (CBD), serving as the primary hub for various activities.

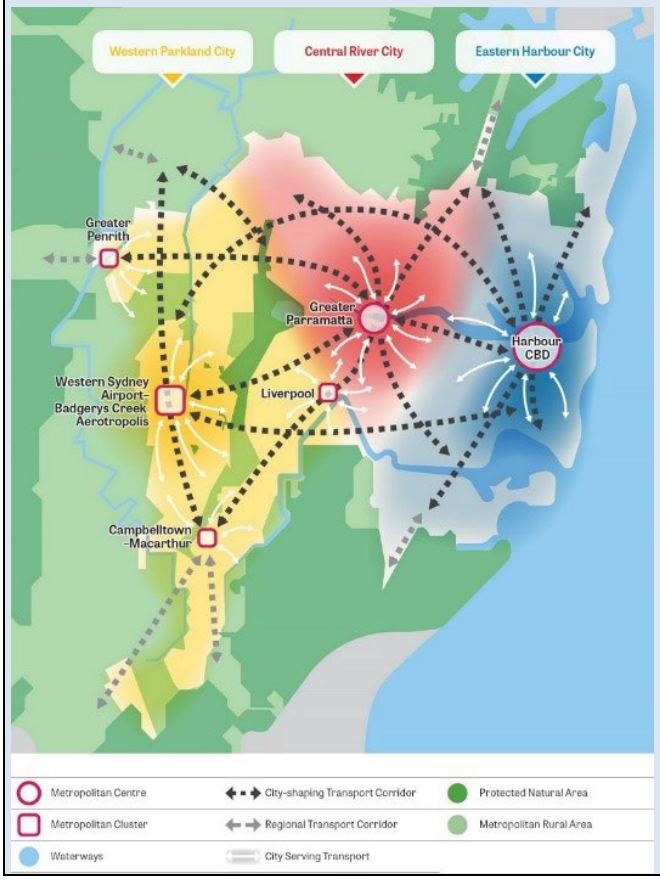
According to Abozeid and AboElatta (2021), key characteristics of a polycentric city include the absence of a dominant leading city and the presence of interconnected yet distinct centres without a clear hierarchy. Polycentricity is considered an important strategy for future urban development as it helps mitigate issues caused by traditional city centralisation such as traffic congestion, air pollution and heat island effects (Liu et al., 2020).

Furthermore, Abozeid and AboElatta's (2021) research highlights that independent polycentric urban environments are strongly associated with achieving better development outcomes. This becomes crucial for community wellbeing as polycentricity can facilitate improved access to various social and commercial services, reducing spatial disparities (Sá Marques et al., 2019).

Case study: Sydney's three cities

Sydney, Australia, is a recent example of an existing city that is attempting to adopt a polycentric approach. In 2019, the Greater Sydney Commission proposed a 40-year vision of Sydney's metropolitan area to be formed into three cities – Eastern Harbour City, Central River City and Western Parkland City (Figure 4.2). Sarkar et al. (2019) argue that the polycentric design of Sydney (and other polycentric cities) should be focused on accessibility as the region should prioritise making jobs accessible in emerging centres rather than focusing on providing transport to one large centre.

Figure 4.2 Map of Sydney's three cities (reprinted from Greater Sydney Commission, 2018, p. 7)



4.3 Urban form in New Zealand

Overall, the literature on New Zealand's urban form primarily focuses on housing, and there are limited sources regarding other aspects of urban form such as layout and land-use mix. The literature on housing mostly focuses on density and typology.

4.3.1 Residential density

Consistent with recent data from Stats NZ (2022a), according to the New Zealand Productivity Commission Te Kōmihana Whai Hua o Aotearoa (2017), approximately 86% of New Zealanders reside in urban areas. The report also indicates that, overall, New Zealand cities have become denser. Despite notable population growth in Hamilton and Tauranga, the rise in density has been marginal. Auckland and Wellington, however, have experienced intensification between 2001 and 2013, leading to an average neighbourhood density increase of approximately 33% during that period.

Ghosh and Vale (2009) suggest that New Zealand urban areas will undergo a gradual change in density, with lower density likely remaining the predominant land use. However, the NPS-UD and MDRS represent a significant shift in how councils plan their urban environments, requiring denser urban form. The NPS-UD facilitates increased housing density by requiring every local authority to amend its regional policy statement to require increased density. More information on the NPS-UD and MDRS is provided below.

In Christchurch, low-density neighbourhoods tend to be in outer areas while higher-density neighbourhoods tend to be in inner-city areas. Following the 2011 Christchurch earthquake where 16,000 properties were damaged and 9,000 properties were deemed uninhabitable, low-density residential neighbourhoods were commonly built in the outer suburbs and mixed-use higher-density dwellings were typically built in the inner-city suburbs (Kusumastuti & Nicholson, 2017).

Bryson and Allen (2017) review definitions of medium-density housing, the common New Zealand typologies and the strategic and policy context of medium-density housing in New Zealand. Their findings demonstrate that an increasing number of territorial authorities are adding medium-density housing goals into their growth management strategies and policies and are supporting growth through policy reform and initiatives such as special housing accords.[5]

4.3.1.1 National Policy Statement on Urban Development and Medium Density Residential Standards

The NPS-UD and MDRS represent a significant shift in how councils plan their urban environments, requiring denser urban form.

The NPS-UD facilitates increased housing density by requiring every local authority to amend its regional policy statement or district plan to reflect the new density provisions (Table 4.1). Tier 1,[6] tier 2[7] and tier 3[8] local authorities were required to notify their intensification plan changes adopting the above policies by August 2022. These plan changes are ongoing.

[5] The Housing Accords and Special Housing Areas Act 2013 provides the ability for the Minister responsible for administration of the Act to enter into a housing accord with a territorial authority to work together to address housing supply and affordability. The Act also allows the Minister to establish special housing areas, which streamlines the process for the construction of qualifying residential developments.

[6] Local authorities located in Auckland, Hamilton, Tauranga, Wellington and Christchurch.

[7] Local authorities located in Whangārei, Rotorua, New Plymouth, Napier Hastings, Palmerston North, Nelson Tasman, Queenstown and Dunedin.

[8] All other local authorities.

Table 4.1 NPS-UD intensification policies

NPS-UD intensification policies	
Policy 3	In relation to tier 1 urban environments, regional policy statements and district plans enable: (a) in city centre zones, building heights and density of urban form to realise as much development capacity as possible, to maximise benefits of intensification; and (b) in metropolitan centre zones, building heights and density of urban form to reflect demand for housing and business use in those locations, and in all cases building heights of at least 6 storeys; and (c) building heights of at least 6 storeys within at least a walkable catchment of the following: (i) existing and planned rapid transit stops (ii) the edge of city centre zones (iii) the edge of metropolitan centre zones; and (d) [within and adjacent to neighbourhood centre zones, local centre zones and town centre zones or equivalent], building heights and density of urban form commensurate with … (i) the level of … commercial activities and community services …
Policy 5	Regional policy statements and district plans applying to tier 2 and 3 urban environments enable heights and density of urban form commensurate with the greater of: (a) the level of accessibility by existing or planned active or public transport to a range of commercial activities and community services; or (b) relative demand for housing and business use in that location

The NPS-UD also introduced a policy on well-functioning urban environments that articulates a set of outcomes for local authorities to use when preparing plans and making decisions and sets direction for the intended outcomes of the NPS-UD. The Ministry for the Environment (2020) defines a well-functioning environment as a planned environment that, as a minimum, has or enables a variety of homes that:

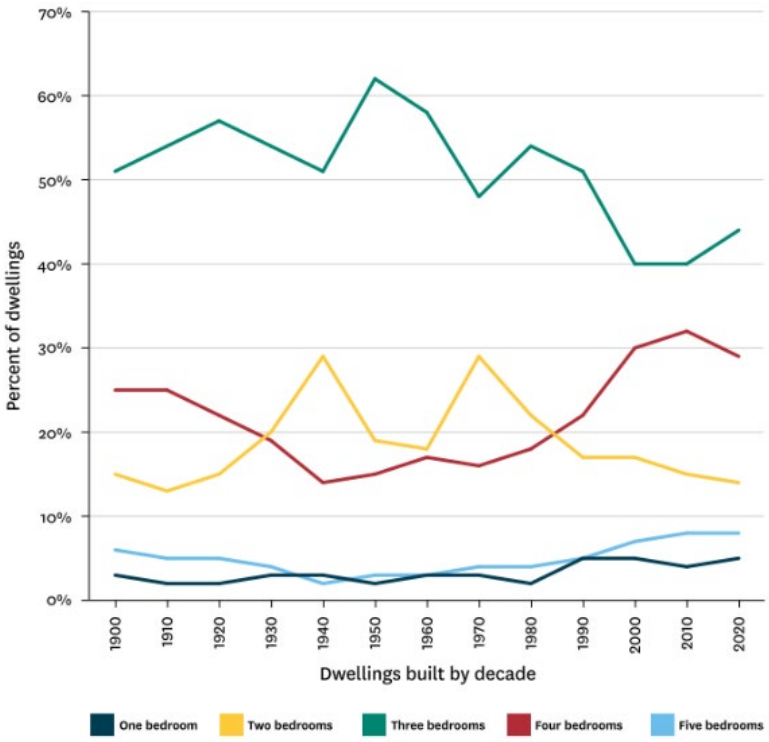
- meet the needs, in terms of type, price and location, of different households
- enable Māori to express their cultural traditions and norms
- have or enable a variety of sites suitable for different business sectors in terms of location and site size
- have good accessibility for all people between housing, jobs, community services, natural spaces and open spaces, including by way of public or active transport
- support and limit as much as possible adverse impacts on the competitive operation of land and development markets
- support reductions in GHG emissions
- are resilient to the likely current and future effects of climate change.

The MDRS were passed into law in December 2021 under the Resource Management (Enabling Housing Supply and Other Matters) Amendment Act 2021. The MDRS allow for building up to three homes of up to three storeys on each site in relevant residential zones without needing resource consent. Each tier 1 local authority is required to include the MDRS in the relevant residential zone of its district plan.

4.3.2 Housing in New Zealand

Across New Zealand, current housing supply is predominantly a mixture of single-storey and double-storey detached homes with the proportion of two-storey dwellings increasing, site sizes decreasing and the number of attached homes increasing (Bryson & Allen, 2017). In June 2023, more townhouses, flats, units (1,551) and apartments (146) were consented in New Zealand than stand-alone houses (Stats NZ, 2023). According to the Ministry of Housing and Urban Development (2023), around 80% of dwellings in New Zealand are detached houses and semi-detached townhouses. The remaining 20% are made up of multi-unit flats and apartments. There is a growing trend towards multi-unit developments but New Zealand's housing stock continues to be dominated by three-bedroom dwellings (Figure 4.3).

Figure 4.3 Bedrooms as a percentage of dwellings built per decade (reprinted from Ministry of Housing and Urban Development, 2023, p. 20)



Moreover, the proportion of four or more bedroom dwellings has increased. In 2018, almost one-third of private occupied dwellings had four or more bedrooms compared to less than a fifth of the housing stock in 1991 (Stats NZ, 2020). The dominance of larger homes in New Zealand is a challenge when considered in the context of New Zealand's ageing and increasingly diverse population, which will require an increasingly diverse housing stock (Ministry of Housing and Urban Development, 2023).

These statistics are unsurprising as research indicates that the 'Kiwi dream' includes lower-density, detached living. The Kiwi dream emerged as a result of past urban policy that limited density as opposed to enabling and supporting it (Opit et al., 2019).

The Kiwi dream is an ideal centred on the ownership of a family home on a quarter-acre section and made famous by Austin Mitchell's (1972) book *The Half-Gallon Quarter-Acre Pavlova Paradise*, which romanticised and satirised life in 1960s New Zealand. Considered in detail by MacGibbon (2023), this cultural cornerstone has its roots in colonial settlement and New Zealand's agricultural history, with most homes in the 19th and early 20th centuries being individual villa-style houses on their own sections. Post-war development in the 1950s and 1960s saw large greenfield, car-centric development rather than development around existing infrastructure. This style of development is inextricably linked with the large increase in the rate of private vehicle ownership that occurred at the same time.

Recent research conducted by Dodd (2020) challenges the commonly held belief that residential development in Hamilton is solely driven by cultural preferences or the Kiwi dream. The study indicates that the market dynamics are characterised by a combination of consumer-led and developer-led influences. While some stakeholders perceived developers as the primary driving force behind housing in Hamilton, others argue that developers can only respond to consumer demand dictated by the market. However, Dodd's findings also shed light on the subjective nature of the concept of the market, revealing how actors within the development space shape it according to their individual values and metrics rather than it serving as an objective indicator of people's needs. These insights suggest that housing density in Hamilton may be more influenced by developer interests rather than being solely guided by the Kiwi dream.

Some of the literature acknowledges that New Zealand has a 'missing middle' or limited provision of medium-density housing such as terraced housing typologies (Bryson & Allen, 2017). However, as noted above, there is a growing trend towards multi-unit developments in recent years. Between 2019 and 2020, consents for multi-unit homes accounted for over 40% of all homes consented nation-wide compared to 20–30% in the 1990s and a low of 15% following the Global Financial Crisis (Stats NZ, 2020). Opit et al. (2019) found that there is strong and growing demand for higher-density housing, and MacGibbon (2023) found that medium-density housing can cater for the needs and preferences of New Zealanders. This is discussed in more detail in section 4.4.1.

Case study: Kāinga Ora large-scale projects

Kāinga Ora is a key driver of housing development in New Zealand, aiming to deliver over 40,000 new medium-density and high-density homes throughout the country across six large-scale greenfield urban development projects in Auckland, Porirua, Te Kauwhata, Waikato and Tauriko over the next two decades (Figure 4.4). These projects involve collaboration with developers, councils, iwi and government agencies.

Figure 4.4 Kāinga Ora large-scale projects map and Northcote Development (reprinted from Kāinga Ora, 2022, pp. 6–7, 10)

Kāinga Ora aims to lead the way with increasing suburban density by introducing more terraced housing, apartments and walk-ups to the housing market. These projects not only increase housing supply and density but also focus on improving infrastructure, creating connected neighbourhoods and enhancing amenities. This approach to urban development prioritises community involvement, cultural celebration and environmental enhancement to build better homes, communities and lives (Kāinga Ora, 2022).

4.3.3 Urban sprawl in New Zealand

While there has been a clear shift towards density in New Zealand, many articles consider urban sprawl (also described as suburban sprawl) to be the prevailing built environment form for much of New Zealand's urban areas, with population growth having been primarily absorbed by greenfield development in the past (Holmes, 2017). In New Zealand, urban development has historically happened at the outskirts of towns and cities, consisting of low-density sprawling suburbs. According to Silva (2019, p. 3), sprawl is 'accepted as an expression of inorganic urban development' and is generally a result of housing policies (or lack thereof), land market constraints and infrastructure.

Silva (2019) has researched urban sprawl in the Auckland context and outlines that Auckland's sprawl is evident in the 'suburbanisation' of Pukekohe. The Auckland Plan identifies Pukekohe as a satellite town that

is enabled for housing intensification. Silva goes on to note that Auckland's sprawl is due to the regulatory planning framework, which encourages sprawl rather than restricting it. Exemplifying this is the use of Future Urban Zones in Auckland's peri-urban areas. The Auckland Future Urban Land Supply Strategy[9] (Auckland Council, 2017) identifies around 15,000 hectares of rural land as suitable for urban development. The expected yield from this area is approximately 137,000 homes or fewer than 10 dwellings per hectare – a distinctly low-density, suburban (or exurban) form. This strategy acknowledges that the development of this currently rural land is dependent upon the funding and delivery of significant infrastructure projects.

Additional factors contributing to urban sprawl include the aforementioned desire for detached housing, low prices for rural land, the use of urban limits, conurbation or polycentrism and weak taxation of undeveloped land (Silva, 2019). Furthermore, the absence of strong regeneration strategies and a lack of priority placed on redevelopment of existing areas has contributed to a focus on sprawl to meet our housing needs. In countries facing immense urban challenges such as China, the redevelopment of existing urban land through urban regeneration and/or renewal strategies has helped to address a scarcity of land resources and provide opportunities for sustainable urbanisation (Huang et al., 2020).

The literature demonstrates that sprawl can lead to negative effects on our urban environment. Lower-density urban form is commonly identified as producing more carbon due to increased use of energy, transportation and intensified use of land and infrastructure (Ghosh & Vale, 2009). Urban sprawl is also associated with many other adverse effects, including increased pollution, lower uptake of active modes, reduced access to primary services, limiting agricultural land, and higher infrastructure and transport costs (Holmes, 2017). In addition, sprawl contributes to the loss of peri-urban spaces (which are commonly highly productive soils in Auckland, Hamilton and Christchurch) and result in greater heat island effects (Holmes, 2017; Silva, 2019).

While all cities in New Zealand continue to grow outwards, there are indications that some of the larger cities may have reached peak rate of sprawl. The Parliamentary Commissioner for the Environment (2023) has reported that, since 2016, Auckland and Wellington have seen more than 70% of new houses developed within the existing urban environment. As land prices increase and population demographics change (in particular, as the population ages), demand for different housing typologies is increasing, with low-maintenance and compact housing with good access to urban amenities starting to displace demand for 'suburban paradise' properties (Jordan, 2020). Furthermore, the introduction of the National Policy Statement for Highly Productive Land 2022[10] will ultimately place an outer limit on the extent of sprawl in many areas around New Zealand's cities. However, as Future Urban Zones are excluded from protection, this policy statement will not alone restrict sprawl in these areas over the coming decades.

4.4 Public aspirations for housing and perspectives on higher-density living

Numerous studies have investigated New Zealanders' housing aspirations, preferences and perspectives on higher densities. Overall, they found that New Zealanders have a strong preference for stand-alone, detached dwellings. This appears to be largely driven by transport and lifestyle choices.

[9] In May 2023, Auckland's draft Future Development Strategy (FDS) 2023–2053 went out for public consultation. Auckland Council is required under the NPS-UD to produce a FDS every 6 years. The aim of the FDS is to promote integrated long-term strategic planning, help councils to set a high-level vision for accommodating urban growth over the long term and identify strategic priorities to inform other development-related decisions. If adopted, this will supersede the Future Urban Land Supply Strategy.

[10] https://environment.govt.nz/publications/national-policy-statement-for-highly-productive-land

4.4.1 New Zealand perspectives on higher-density living

The literature indicates a mix of perspectives on higher densities in New Zealand. Ghosh and Vale (2009) found that people's preferences are generally driven by their lifestyle choice, with many preferring the suburban Kiwi dream. However, compact living can be encouraged by the introduction of high-quality, high-density typologies (Opit et al., 2019; Ghosh & Vale, 2009).

Holmes (2017) investigated housing preferences in Auckland supplemented by a comparison of findings from Wellington and Hamilton based on findings from Auckland Council's People's Panel, a 2015 survey regarding Aucklanders' preferences regarding housing, transport and neighbourhoods, looking at housing choice for over 3,285 Auckland households (Holmes et al., 2016). The findings demonstrate that those interviewed strongly preferred detached housing, with approximately 80% of respondents stating that detached housing was their preferred typology and 60–70% of respondents stating that apartments were their least preferred typology. The findings indicate that there is an unmet demand for accessible medium-density housing, with some households willing to trade off dwelling size and neighbourhood type for higher accessibility or lower house prices. More survey respondents drove than would like to and cited long journey times, unreliable services, a lack of infrastructure and safety concerns as key barriers to active and public transport. Households who prefer lower density were also found to be more likely to occupy their favoured dwelling typology and use their preferred mode of transport. In contrast, those preferring high accessibility or lower house prices were more likely to experience disparity between their preferred and current dwelling type and were less likely to use their preferred mode of transport (Holmes, 2017).

Carroll et al. (2011) explored the everyday experiences of parents and children living in inner-city apartments in Auckland. The findings demonstrated that the benefits of apartment living include walkability, convenience, affordability and additional security. Disadvantages noted in the findings included 'stranger danger', noise, poor design and lack of storage, play space and natural light. Overall, many respondents considered that apartments were not designed with families in mind and would be better suited to empty nesters. The paper noted that these concerns relating to apartment living still often applied to suburban living too and that apartments and inner-city living could yet be designed to be more appropriate for the needs of families.

Bryson (2017) investigated the attitudes of New Zealanders towards alternative typologies, including medium-density housing. The study revealed a significant preference for mainstream stand-alone dwellings over medium density, with better privacy, perceived safety of private property and common visual appeal being the most common reasons cited. In addition, despite Auckland having higher-density housing, Wellington residents were the least hesitant to live in medium-density housing compared to Auckland and Christchurch residents. The author recommended that awareness needs to be enhanced as many benefits of alternative housing are unrealised by New Zealand residents.

Opit et al. (2019) investigated the housing preferences of Millennials (born between 1981 and 1996) and how experiences influence perspective on urban environments. These results were drawn from 24 semi-structured interviews with young adults based in Auckland aged between 25 and 30 and living in a range of housing tenures. Overall, the findings demonstrate that there is an aspiration among younger populations for an urban lifestyle in higher-density suburbs in proximity to the CBD. Moreover, younger people are more likely to acclimatise to inner-city, higher-density living through positive living experiences, which can be cultivated through contemporary high-quality dwellings in areas where younger people want to live. Respondents also enjoyed the community areas that are commonly included in inner-city suburbs – the essential and social amenities that reduce their need to travel by private vehicle. This highlights the interconnected nature of land use and transport, with transport choices appearing to strongly influence the housing choices of respondents as many particularly enjoy the transport options associated with Auckland's inner-city suburbs.

Kusumastuti and Nicholson (2017) investigated the preferences on mixed-use neighbourhoods in Christchurch. The study found that most respondents would prefer to live in proximity to a supermarket and playground while only a minority would prefer to live near offices or retail. The preference for primarily single-use neighbourhoods rather than higher-density, mixed-use neighbourhoods has been attributed to amenity values, specifically the need for quietness and privacy, which are considered to be better in low-density outer suburbs. This is consistent with findings from BRANZ (Bryson, 2017), which note there is resistance to medium-density and higher-density neighbourhoods in New Zealand, with lowered amenity cited as the key reason for this.

These findings show respondents felt that higher-density developments could reduce the attractiveness of inner-city suburbs. In contrast to findings from Opit et al. (2019), Kusumastuti and Nicholson (2017) found that an increase in commuting time had only a small impact on people's choices to live in outer, low-density suburbs. They do argue, however, that the primary driver behind the popularity of low-density outer suburbs was affordability, and they noted that, while first-home buyers preferred these areas, those moving into their second or subsequent home were more likely to buy in the inner, mixed-use suburbs.

4.4.2 Urban amenities and green space

The importance of green space in urban environments is identified in the literature. Freeman et al. (2021) present results on exposure to nature and green spaces for families in New Zealand with families considering nature and their connection to nature to be of high value to them. Green spaces were used to meet friends, to engage in spontaneous play and to relieve stress and pressure. All respondents exhibited an intimate connection with nature and enjoyed what natural spaces had to offer. However, this study showed that most families did not prioritise local green space and instead were prepared to travel to wilder green spaces further from home. According to Thompson et al. (2016), having access to green space in more deprived communities can enhance individuals' sense of belonging and reduce social isolation, which generally leads to more positive outcomes among city residents.

Research by Jordan (2020) indicates that private outdoor space, green outlook and access to public space are important considerations for most when choosing housing. A preference for private open space (back yards) was evident in this research. It also highlighted that attitudes towards housing intensification are affected by perceptions of poor quality and that councils and developers need to deliver best-practice urban design that addresses these concerns and preferences if they are to increase market appeal of medium-density housing.

A recent report by the Parliamentary Commissioner for the Environment (2023) examined the importance of green infrastructure in our towns and cities. It found that, from 1980 to 2016, the amount of green space per person decreased by a minimum of 30% in Auckland and at least 20% in Hamilton, attributing this gradual loss to infill development and the shift towards larger houses on smaller sections in new subdivisions. Intensification trends therefore risk diminishing existing networks of urban green space, especially infill townhouse development typologies that are commonly occurring in New Zealand cities. To help counteract this loss, the report recommends building upwards rather than outwards, mandating that local authorities provide for urban green space to avoid creating less liveable urban environments, improving existing public green space and providing it from the outset in new subdivisions on the city fringe.

Case study: Hobsonville Point high-density housing experiences

Haarhoff et al. (2019) report on the case study of Hobsonville Point in northwest Auckland – New Zealand's largest masterplanned residential development, which comprises a high proportion of attached building typologies. Overall, the case study finds that residents were very satisfied with their dwellings, their sense of community, the area's walkability and their neighbourhoods.

Most respondents (over 67%) were living in higher-density, attached housing types such as apartments, terraced houses and duplexes. Satisfaction with dwellings was high with the variety of the built environment cited as a key reason. However, there were several areas that could be improved such as private areas facing streets and privacy in back yards.

Initially, there were questions regarding whether the development could attract buyers given its location in Auckland's outer suburbs. However, Hobsonville Point was well marketed and constructed an idealised image of coastal living under the slogan 'moments away, worlds apart'. The development was also staged in a way that supported Hobsonville Point as a destination, establishing the social infrastructure (farmer's market, coastal walkway, schools and cafés) prior to most of the residential development. The masterplan for Hobsonville Point aimed to integrate housing with the natural environment and be socially sustainable, encouraging social interaction through design features such as street-facing dwellings and open spaces (Figure 4.5 and Figure 4.6).

There were low levels of dissatisfaction with the neighbourhood, with 37% of respondents stating they were very satisfied with their neighbourhood and an additional 40% stating they were satisfied. Many noted that the prevalence of green space in the area contributed to their sense of satisfaction.

Figure 4.5 Hobsonville Point coastal walkway

Source: https://hobsonvillepoint.co.nz

Figure 4.6 Higher-density housing and an example of public space in Hobsonville Point

Source: https://www.newground.co.nz/investments/hobsonville-point-mixed-tenure-housing; https://www.aucklandcouncil.govt.nz/parks-recreation/get-outdoors/aklpaths/Pages/path-detail.aspx?ItemId=72

Hobsonville Point includes approximately 24 hectares of green space with an abundance of reserves, parks and the coastal walkway. Of note, the research demonstrates that satisfaction is strongly correlated with the quality of the public realm and its design. In this instance, the public realm was prioritised as part of the area's vision. However, Haarhoff et al. note that the same level of prioritisation may not occur from private developers and market-driven developments. Their findings suggest that public spaces and amenities play a key role in housing satisfaction. This is consistent with a comprehensive sustainability assessment that found that 98.5% of respondents considered Hobsonville Point a great place to live and that the particular strengths of the community included walkability, the natural environment, sustainable dwellings, quality of the public realm and the design of the street network (Lietz & Bijoux, 2014).

Dolan (2018) considered community formation in intensified urban development focusing on three Auckland developments, including Hobsonville Point. Findings from interviews with Hobsonville Point residents revealed that the initial wave of residents (from 2013) moved to Hobsonville Point due to its comparatively lower housing prices. As the development progressed, amenities were established, fostering a sense of community. By this stage, retirees or those planning for retirement chose to live in the area due to the smaller, better-quality, easy-to-maintain and more affordable homes. Dolan also found that, for younger residents with children, proximity to schools and early childcare facilities was a key attractor. Additionally, the sense of safety within the pedestrian-friendly environment of Hobsonville Point appealed to residents. The study also highlighted that Hobsonville Point had a strong sense of community with kind, supportive and friendly residents. Dolan found that the developer of Hobsonville Point prioritised the creation of humanised landscapes that encouraged connections between people and provided an enjoyable living environment and the careful masterplanning of Hobsonville Point not only supported the formation of a thriving community but also fostered meaningful social interaction. This research revealed that, in comparison, other infill developments did not achieve as high levels of social cohesion. These findings suggest that achieving positive outcomes is more attainable at a larger scale where masterplanned initiatives can effectively bring together diverse elements rather than in fragmented infill projects.

Case study: London perceptions of high-density housing

While many international studies have demonstrated that the experiences of children in apartments is not favourable, Carroll et al. (2011) noted many studies on this topic have tended to involve families in social housing and it is difficult to differentiate adverse impacts of high density from those due to higher deprivation. Blanc et al.'s (2020) research looked at 14 high-density developments in London and explored who lived in these developments, why residents chose to live there, pros and cons of high-density living and residents' aspirations for housing in the future. The case studies generally included a mix of housing tenures, including owner-occupiers, private tenants and/or social tenants. One development only included social tenants and three developments only included owner-occupiers and private tenants, with the other nine comprising a mix of all housing tenures. It is important to note that these developments were generally high-rise apartments (with over 200 units), which is a significantly higher dwelling density than what can be considered high density in New Zealand. The findings indicate the residents primarily comprise childless singles or couples, with 78% of respondents living in a household with one or two people. Overall, 13% of households studied had children compared to 31% of households London-wide. The age of the development generally correlated with the age of residents, with younger people living in newer developments and older people living in more established developments. Of the residents surveyed, their reasons for choosing high-density living were transport links (68%), price (43%) and the neighbourhood (33%). The advantages and disadvantages identified in this research are relatively consistent with the findings of Carroll et al. (2011) and Haarhoff et al. (2019). Advantages included a lower fear of crime, good views, a good sense of community (especially in complexes where most residents were owner-occupiers), communal spaces (where provided) and being in proximity to public green spaces, shops and amenities. Disadvantages included lack of daylight in lower levels, not enough privacy and limited access to outdoor living space.

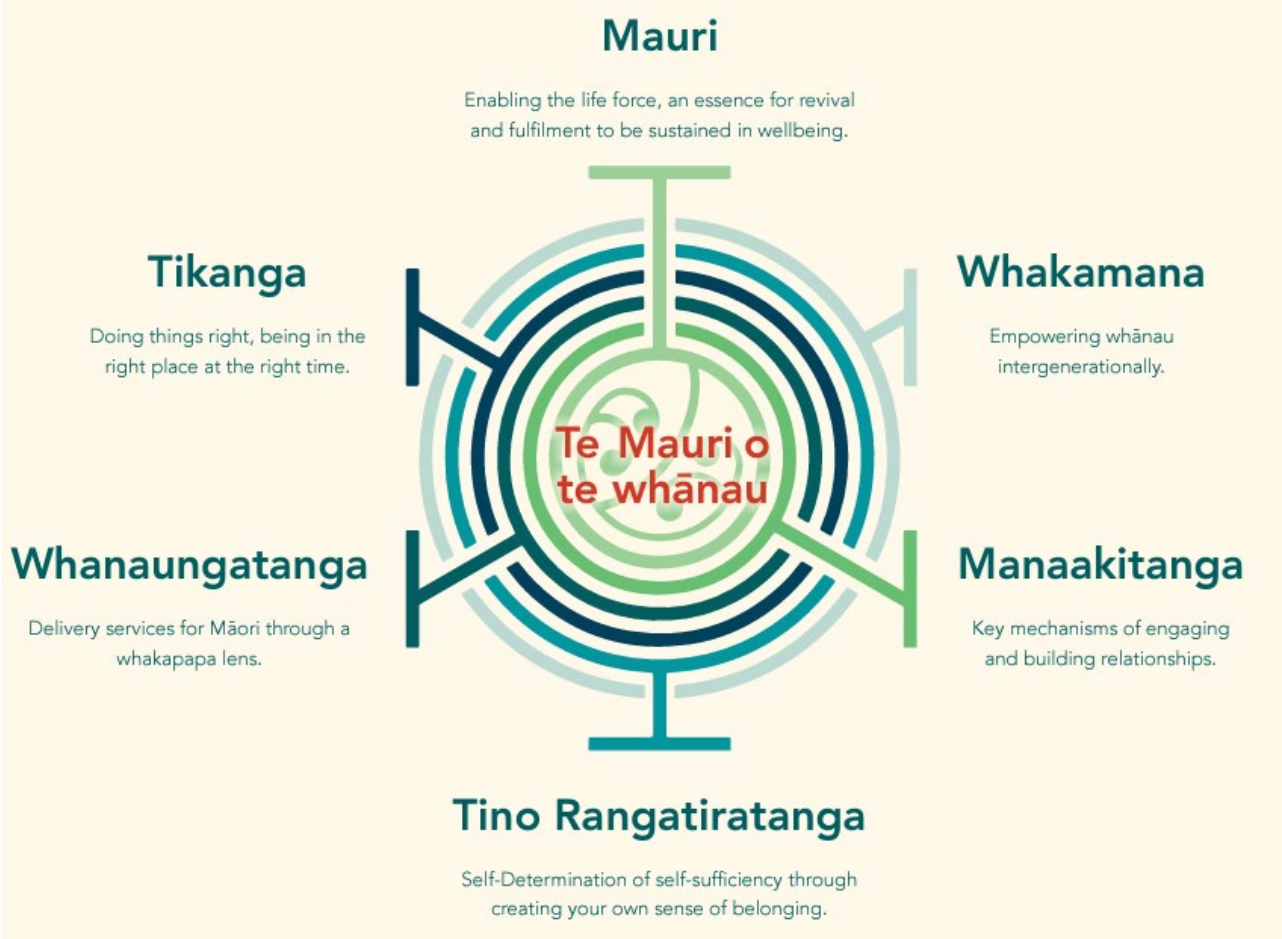
4.5 Māori housing aspirations

While Māori are not a homogeneous group and housing aspirations are likely to vary depending on the individual, whānau, hapū or iwi, it is understood that Māori broadly want to create spaces for Māori to be proudly Māori, to be major stakeholders and collective owners of land and, importantly, to be prosperous and comfortable urban residents with mana (New Zealand Productivity Commission, 2017). For mana whenua and mātāwaka (Māori who do not live on ancestral whenua), urban-related interests align with rangatiratanga and kaitiakitanga and are underpinned by mana. Moreover, the preservation of wāhi taonga, places or sites that are significant to Māori, and papakāinga are highly important.

4.5.1 MAIHI Ka Ora: The National Māori Housing Strategy

Māori and Iwi Housing Innovation (MAIHI) Ka Ora: The National Māori Housing Strategy represents the aspirations of Māori for improved housing outcomes for future generations and their whānau over the next 30 years (Ministry of Housing and Urban Development, 2022). Co-designed with input from Māori in the housing sector, this strategy emphasises genuine partnership between Māori and the Crown. It is guided by the MAIHI principles and framework (Figure 4.7).

Figure 4.7 MAIHI principles and framework (reprinted from Ministry of Housing and Urban Development, 2022, p. 6)



The overarching vision of MAIHI Ka Ora is to ensure that all whānau have access to safe, healthy and affordable homes with secure tenure across the entire Māori housing continuum.

The shared priorities and ultimate goals of the MAIHI Ka Ora framework are outlined in Table 4.2.

Table 4.2 MAIHI Ka Ora shared priorities and ultimate goals (Ministry of Housing and Urban Development, 2022, pp. 23–31)

Shared priorities	Ultimate goals
Māori Crown partnerships	To work in partnership where the Crown and Māori achieve balance through a collaborative work programme that strengthens housing solutions for whānau.
Māori-led local solutions	Māori leading and providing local housing solutions to whānau.
Māori housing supply	The number of Māori-owned homes, iwi and hapū-owned houses can meet the housing needs of all Māori.
Māori housing support	Whānau have better access to effective support that is fit for purpose and enables them to attain and maintain their preferred housing option.
Māori housing system	The system supports Māori to accelerate Māori-led housing solutions.
Māori housing sustainability	Whānau are supported to achieve mana-enhancing housing solutions on their whenua. Māori are able to sustain a connection to their own land through housing and their housing is innovative and responsive to the impacts and effects of climate change.

4.5.2 Papakāinga

Berghan (2020) examines the potential to combine western co-housing models with papakāinga concepts to create greater opportunities for Māori communities to enter the housing market and discusses that there are several similarities between western housing and papakāinga such as shared spaces and the desire for social, environmental and economic sustainability. By incorporating kaupapa Māori values into co-housing typologies and changing mainstream notions of ownership and property in ways that support inclusive and affordable housing, Māori communities and other minority groups can be empowered. Kake and Paul (2018) identify that Māori design principles have potential to significantly impact future neighbourhood regeneration and housing developments, informing more culturally attuned spatial design processes and outcomes.

In recent years, the development of papakāinga housing has flourished throughout the country. To support the momentum, Kāinga Ora and Kiwibank have partnered to create a home loan initiative called the Kāinga Whenua Loan Scheme to help Māori achieve home ownership on papakāinga (Kāinga Ora, 2023).

Case study: Kāinga Tuatahi

Kāinga Tuatahi is a medium-density papakāinga development completed in 2016 comprising of 30 homes siuated in Takaparawhā (Bastion Point), Auckland (Auckland Council, 2016). The project was led, designed, developed and financed by Ngāti Whātua Ōrākei solely for the occupancy of Ngāti Whātua hapū families. Kāinga Tuatahi exemplifies Māori-led papakāinga design and purpose, which reflects not only kaupapa Māori values but is tailored to suit the needs of Ngāti Whātua members and their families appropriately.

Ngāti Korokī Kahukura Papakāinga, completed in 2020, is a smaller 10-home development that aimed to bring whānau back to the community in Maungatautari, Waikato (Te Puni Kōkiri, 2021). The development was financially supported by Te Puni Kōkiri Ministry of Māori Development and Westpac (2019). One of the unique features of the site is the collective eco-friendly on-site wastewater system that reflects sustainability and the belief that Ngāti Korokī Kahukura have on avoiding any human waste contaminating land or water sources.

4.6 Factors driving urban form

The literature highlights several key factors driving urban form. This section discusses the literature in relation to legislation and policy in New Zealand, environmental and topographical factors, and land values.

4.6.1 Legislation and policy

Legislation and policy have had a large influence on urban form in our towns and cities. Over the last 25 years, responsibility for shaping urban form in New Zealand has been largely entrusted to local government through legislative frameworks for land-use planning and environmental management, infrastructure funding, urban development and the goals of communities (Department of Internal Affairs, 2008). However, these overlapping frameworks were found by the Randerson panel review of New Zealand's resource management system to create complexity and misalignment (Resource Management Review Panel, 2020). An option considered to address this, was the reform of the resource management system, including the introduction of spatial planning to help integrate planning across the RMA, Local Government Act 2002 and Land Transport Management Act 2003 on a national and regional basis.[11]

In September 2023, New Zealand's Resource Management Act 1991 (RMA) was replaced with the Spatial Planning Act 2023 (SPA) and Natural and Built Environment Act 2023 (NBEA). While the primary objective of the NBEA is to protect the environment, it also strives to enable housing supply, affordability and choice and facilitate timely provision of appropriate infrastructure to support development. The SPA aims to set long-term strategic goals to facilitate the integration of legislative functions across the resource management system. This includes a requirement for central government, local government and Māori to collaborate as a regional planning committee to create a regional spatial strategy.

As part of the resource management reforms, New Zealand has also introduced a National Planning Framework that provides high-level planning direction to regional and local councils. This includes the NPS-UD.

4.6.2 Spatial planning

Spatial planning is considered an effective tool to coordinate and plan infrastructure at the strategic level and, when done right, can reduce the cost of infrastructure needed to accommodate growth (Te Waihanga, 2022). Spatial planning typically includes two key elements (Sense Partners, 2021):

- Well-defined spatial plans that outline where cities should develop.
- Narrowly defined spatial strategies that view cities as complex systems and set out the general parameters of where infrastructure development might occur.

Committing to a long-term multi-scalar view, spatial planning allows stakeholders (including infrastructure providers) to align their projects with a shared vision (Te Waihanga, 2022). Furthermore, spatial plans typically identify and protect land for future infrastructure, providing more certainty. Currently, six high-growth urban areas in New Zealand have an agreed spatial plan developed through an urban growth partnership (UGP). UGPs have been established as part of the Urban Growth Agenda – Te Tūāpapa Kura Kāinga to improve coordination and alignment between central and local government and mana whenua in New Zealand's high-growth urban areas. The UGPs aim to improve housing, land use and infrastructure outcomes through a long-term and integrated approach to land use and infrastructure planning.

Spatial plans throughout New Zealand have also reflected a commitment to intensifying urban form. In the Auckland Plan, a key direction is to develop quality compact urban form (Auckland Council, 2018). This is reflected in the Auckland Unitary Plan operative in part 2016,[12] which introduced higher-density zones (such as the Terrace Housing and Apartment Buildings Zone) and targeted higher-density living over time.

[11] Legislation to repeal the NBEA and SPA was passed in Parliament in December 2023 – see https://environment.govt.nz/news/nba-spa-repeal.

[12] https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/unitary-plan/Pages/the-auckland-unitary-plan-operative-in-part.aspx

In the Waikato, the spatial plan Future Proof seeks to enable quality denser housing options that allow the natural and built environments to coexist and prescribes net target densities (Figure 4.8) to be achieved over time in greenfield locations and defined intensification areas (to be determined).

Figure 4.8 Example of intensification targets within defined intensification areas and greenfield locations

Location	Urban environment under the NPS	Net target densities *(dwellings per hectare)* to be achieved over time in defined locations[4]	Future public transport service
Pookeno	Tier 1 (TBC)	25-35 in defined intensification areas 20-25 in greenfield locations	TBC
Tuakau	Tier 1 (TBC)	25-35 in defined intensification areas 20-25 in greenfield locations	TBC
Te Kauwhata	No	25-35 in defined intensification areas 20-25 in greenfield locations	TBC
Ohinewai	Tier 3 (part of Huntly urban environment)	20-25 in greenfield locations	TBC
Huntly	Tier 3	25-35 in defined intensification areas 20-25 in greenfield locations	TBC
Taupiri	N/A	25-35 in defined intensification areas 20-25 in greenfield locations	TBC
Ngaaruawaahia	Tier 1	30-50 in defined intensification areas 20-25 in greenfield locations	Rapid and Frequent

Source: https://futureproof.org.nz/the-strategy

4.6.2.1 Integrated transport and land-use planning

There is a body of international research that suggests that spatial planning alone will not result in a sustainable urban form. Rather, an integrated approach to spatial and transport planning processes is needed.

Yigitcanlar and Teriman (2014) evaluate and discuss the effectiveness of traditional policy and planning instruments in achieving sustainable urban development, finding that, to date, sustainable urban development has not been achieved in large scales anywhere around the world despite the concept being around for some time. They identify several issues associated with urban planning and call for a more holistic and integrated urban planning and development process to achieve sustainable development. This is echoed by Lee (2020), who argues transport planners and spatial planners tend to work in silos due to time and resource constraints rather than collaborating for an integrated approach.

> *[S]patial planning policy in rapidly growing cities takes a "land (housing) development first, transport development later" approach in order to accommodate continuously increasing migration flows to urban areas. Large-scale housing development in peripheral areas is often planned without public transportation development. In the case of transport planning, attention is mainly given to enhancing accessibility to the commercial centres and reducing congestion, rather than providing sufficient transport networks to wider areas such as new satellite cities.* (Lee, 2020, p. 2)

According to Lee (2020), this disintegrated approach to urban development practice results in negative social, economic and environmental costs over time such as poor access, increased congestion and socio-economic inequities. Instead, the author identifies the need for greater integration of spatial and transport planning processes from the strategic planning stage to the operational stage of urban development projects.

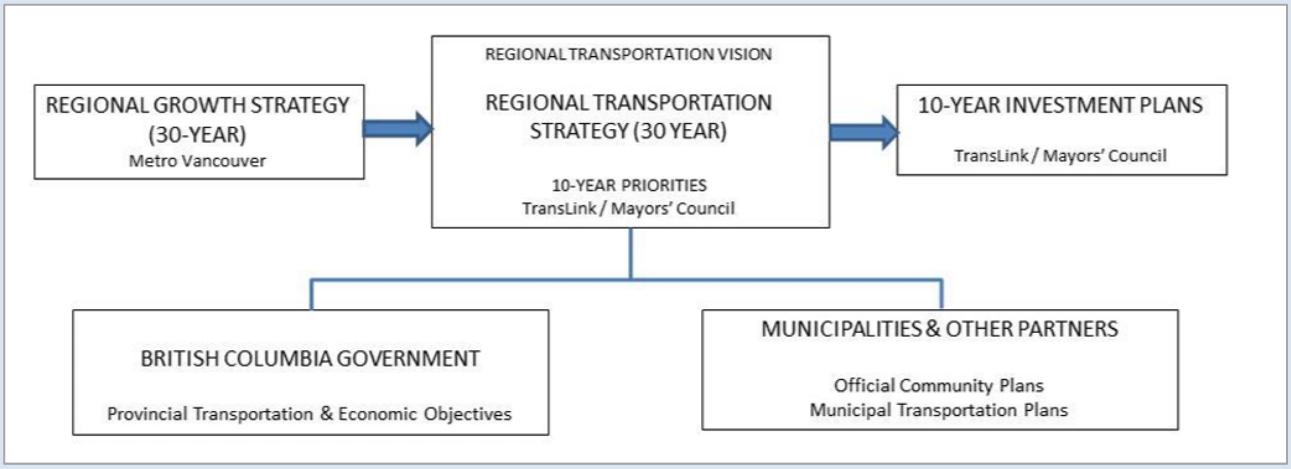
Here in New Zealand, Doran et al. (2022) identified similar barriers and facilitators of strong integrated transport and land use. The main barriers included status quo biases, tensions between different legislation, the complexity of the current planning framework, capacity challenges at local government levels and uncoordinated national and local policies. This research also cites various enablers and opportunities to facilitate transport and land-use integration in New Zealand. These include national policy direction, resource management reforms, improved funding mechanisms, Kāinga Ora project implementation capacity and the adoption of the One Network Framework for integrated planning.

Case study: Vancouver integrated regional planning

Vancouver, Canada, is widely recognised as a global leader in urban sustainable practice and planning. With its densely populated downtown area, walkable neighbourhoods and strong integration with natural surroundings, it exemplifies the commitment to environmental stewardship (Rosol & Temenos, 2019). Vancouver's success has been attributed in part to its governance model, which increases collaboration around infrastructure, encourages joint funding projects and engenders future engagement (Sweeney, 2023). Learnings from Vancouver demonstrate it is crucial to establish city-wide priorities that are integrated into all departments' plans and programmes, fostering collaboration and coordination. Incentivising joint-funded projects aligned with city-wide priorities, creating a centralised approach to delivery and embracing a culture of adaptability and stakeholder feedback and collaboration can lead to long-term outcomes.

The Metropolitan Vancouver Region has successfully implemented an integrated approach to regional planning guided by strategic documents such as the Regional Growth Strategy (RGS) and the Regional Transportation Strategy (RTS) (Melchor & Lembke, 2020). These plans align land use and transportation vision (Figure 4.9) to ensure a unified and sustainable approach to growth management. The RGS is a comprehensive land-use plan that outlines the region's goals, actions and strategies. It focuses on guiding development to support efficient transportation, infrastructure, community services, air quality protection and GHG emissions reduction, particularly through Frequent Transit Development Areas that enable intensified development proximate to frequent transit services. The RGS works in conjunction with the RTS to achieve sustainable transportation while promoting greater density to reduce congestion, improve infrastructure economics, enhance retail and service centres and increase accessibility for a thriving social community.

Figure 4.9 Vancouver's integrated growth strategy (reprinted from Melchor & Lembke, 2020, p. 14)



According to Tan et al. (2013), the regional plans provide coherence and continuity to the planning process, resulting in successful transit-oriented communities with higher densities than other North American cities.

While Vancouver's regional planning strategies and consistent overarching vision is considered a key driver of Vancouver's success, they note that the public's shared belief in working towards the vision of the 'world's most liveable city' (public buy-in) is also a key driver.

Vancouver's success has also driven broader outcomes by prioritising an equitable and accessible transport system. Vancouver serves as a model for transit planning by providing better service for low-income individuals in both short and long journeys when compared to other cities (Adli et al., 2019).

From Vancouver's success, we can learn that resilient urban infrastructure requires a long-term planning mindset that considers a range of impacts.

4.6.3 Environmental and topographical considerations

The physical environment has a highly influential impact on urban form and transport networks. Elements and features of the natural environment such as climate, topography and the presence of water features (harbours, rivers, streams) and land features (mountains, ridges, slopes) influence the location of initial development and growth of development and transport networks (Daniels & Mulley, 2012).

New Zealand has a highly varied environment and terrain, which creates different barriers and enablers to development throughout the country. For example, in 2019, Wellington City Council (2019) determined that the city has a shortage of residential development capacity as the area is physically constrained between the harbour and the hills, creating a lack of flat land for further expansion in the inner-city suburbs.

After the 2011 Christchurch earthquake, thousands of people migrated from the inner city to the southern suburbs of Christchurch and neighbouring towns (such as Rolleston) due to a lack of natural barriers and abundance of flat greenfield land (Dionisio et al., 2015; Stirling, 2020).

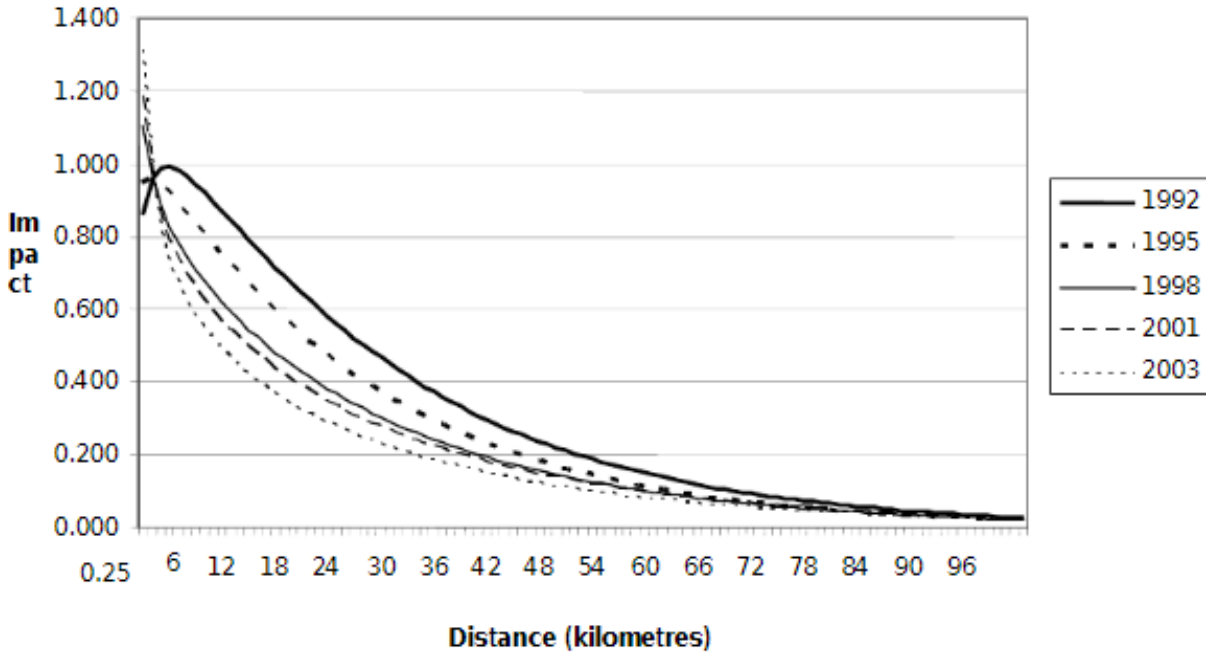
However, outer-suburban neighbourhoods have experienced several problems associated with sprawl in recent years, including increasing resource stress and loss of identity and amenity value (McDonald, 2021). Multiple areas of residential red zoned land (such as Horseshoe Lake and Bexley) remain vacant and infeasible to develop on due to the severe damage caused by the earthquake (Mitchell et al., 2019).

4.6.4 Land values

Land values also influence urban form. Research shows that land nearer to the city centre is more expensive than land at the periphery, which can impact development feasibility. It also demonstrates that inner-city areas are more valuable, which further emphasises the importance of ensuring planning policy supports denser urban form to enable more people to live in well-connected areas with high amenity.

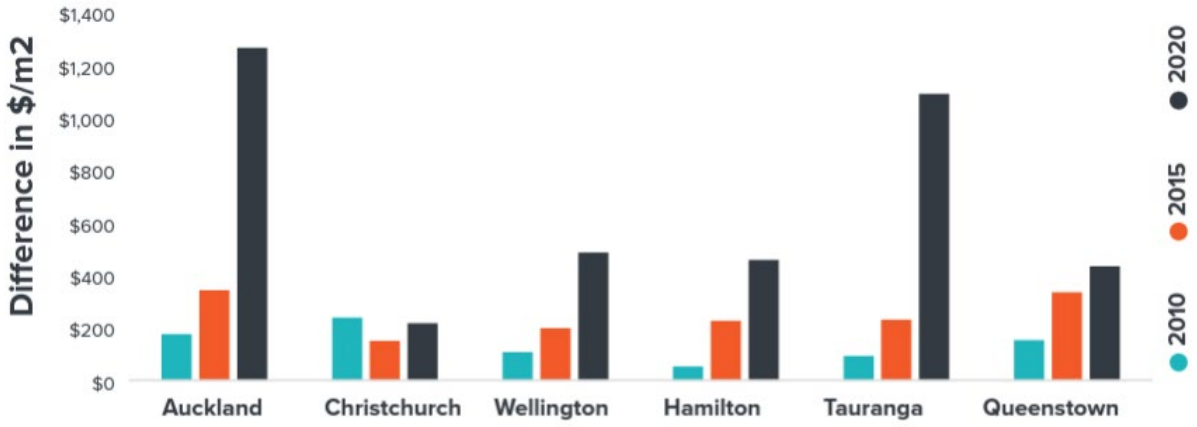
Grimes and Liang (2008) found that land prices within monocentric urban environments tend to decrease from the centre to the periphery of the city (Figure 4.10). The ratio of land values from the city centre to outer areas has increased over time, and land in proximity to local nodes is more valuable than land further from local nodes. Land is valued more highly near the coast than non-coastal areas.

Figure 4.10 Impact of distance from Auckland CBD on real land values (reprinted from Grimes & Liang, 2008, p. 36)



Te Waihanga New Zealand Infrastructure Commission (2023) found that most cities in New Zealand demonstrated substantially higher land prices for urban-zoned land versus rural-zoned land. In Auckland, value disparity between urban-zoned land and nearby rural-zoned land has significantly increased over the past decade, with a premium of nearly $1,300 per square metre in 2020/21 compared to less than $200 per square metre in 2010/11 (Te Waihanga, 2023). Tauranga exhibits a difference of $1,100 per square metre, while Wellington, Hamilton and Queenstown range from $400 to $500 per square metre (Figure 4.11).

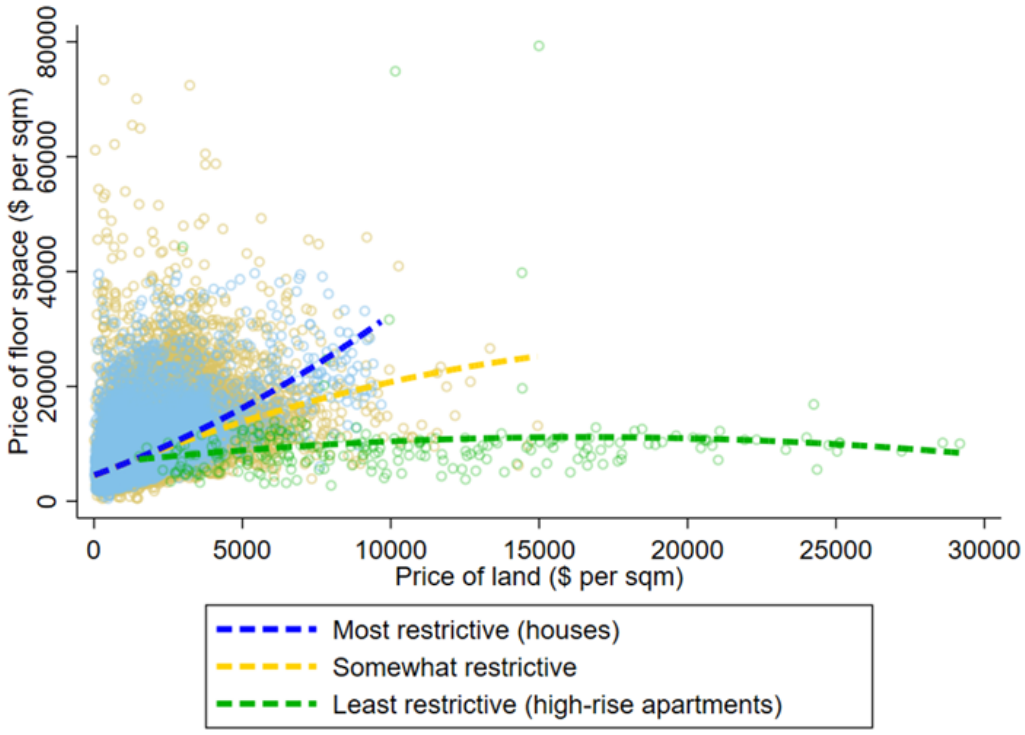
Figure 4.11 The price premium of urban-zoned land in New Zealand cities – difference in land values across rural-urban zoning boundaries (reprinted from Te Waihanga, 2023, p. 6)



Funding for multi-unit developments, particularly apartments, stalled following the Global Financial Crisis, and many finance companies financing apartment developments went into liquidation. It took several years for the industry to bounce back (Johnson et al., 2018). Nevertheless, it is worth noting that the introduction of planning policies promoting higher-density development may have an impact on the dynamics discussed above.

In a cost-benefit analysis for NPS-UD on behalf of the Ministry for the Environment, PwC (2020) similarly found that land prices increase with proximity to the city centre (due to good accessibility and shorter commutes) but the impact on floor space prices is highly dependent on the zoning. For example, rising land values drive up the prices of floor space in areas with strict zoning (such as within single house zoning). In contrast, in areas with higher-density zoning, there is a weak or non-existent relationship between land values and the floor area price (Figure 4.12). Interestingly, PwC found that land that is priced between $5,000 and $30,000 per square metre does not appear to drive housing prices up at all in high-density zoning areas, and therefore intensification policies are fundamental to decoupling land prices from dwelling prices in high amenity areas, allowing residents to sacrifice space rather than location. Given councils' NPS-UD plan changes are yet to be adopted, it is not clear whether these policies will encourage developers to deliver denser urban form.

Figure 4.12 The relationship between the price of floor area and land values for residential properties in Auckland (reprinted from PwC, 2020, p. 10)



Research suggests that land closer to the city centre is more expensive, highlighting the value of inner-city areas. To promote well-connected living in high-amenity areas, it is crucial for planning policies to support denser urban forms. However, the impact of these policies on land prices and housing affordability may vary depending on zoning regulations. Intensification policies can potentially decouple land prices from dwelling prices in high-density zones, allowing residents to prioritise location over space.

4.7 Relationship between urban form and transport emissions

New Zealand's GHG emissions from transport are high, with 38% of New Zealand's carbon dioxide emissions being produced by transport (Stats NZ, 2022b). The recognition of this number is a step towards achieving the government's 2050 net zero GHG emissions target (Ministry for the Environment, 2022a). It highlights both the potential and necessity that the transport sector has to reduce emissions and achieve this target. This section highlights the role that urban form can have and its capacity to achieve a reduction in transport emissions.

While there are a large number of studies that explore the relationship between urban form and enabled transport emissions, there is limited evidence in the literature that captures both the enabled and embodied emissions of urban form characteristics. This further highlights the knowledge gap that this research seeks to address.

A study of US urban areas suggests that GHG mitigation can be achieved through three different transport approaches but all three areas must be simultaneously addressed as regression in one area can offset emissions savings from the rest (Hankey & Marshall, 2010; Chapman, 2008):

- More efficient vehicles.
- Lower GHG fuels.
- Reduction in VKT.

Of these three approaches, VKT reduction is the most prominent theme in the research in relation to emissions reduction through urban form. When people take shorter and fewer private vehicle trips, they reduce their emissions.

4.7.1 Reduction in transport emissions and VKT through urban form characteristics

According to Hankey and Marshall (2010), the promotion of specific types of urban development such as compact growth can achieve moderate reductions in carbon emissions (2010). There is a correlation between compact/centralised urban form and vehicle ownership and use, with modest reductions observed (Donovan & Munro, 2013).

Regional accessibility refers to a location relative to regional activity centres (CBDs or other major employment centres) and the number of jobs and services within a given travel distance or time. According to Litman and Steele (2024), regional accessibility has little effect on trip generation but has the largest impact on trip length and mode choice compared to other urban form characteristics. If people live further from an urban centre where there are a high number of jobs and zones of attraction, they will drive significantly further annually than if they lived in a neighbourhood that is closer to an urban centre.

Connectivity and intersection density are some of the greatest influences on travel activity of all land-use factors (Ewing & Cervero, 2010; Hachem, 2016). Enhanced connectivity and increased directness of travel encourages walking and cycling uptake by reducing travel distances, and shortcuts that ensure these modes are more direct than driving can reduce VKT (Litman & Steele, 2024).

Neighbourhood design and distance to business/attraction centres can have an impact on transport emissions (Hachem, 2016). Centricity factors such as activity concentration in multi-modal centres with land-use mix can reduce the number of trips and distance of travel between destinations, enhancing the potential for alternative mode use and reducing car trips (Litman & Steele, 2024; Hachem, 2016).

Density often receives a lot of attention. While it does tend to reduce travel distances, individually it has little impact on the number of trips people take (Litman & Steele, 2024). Density on its own was shown to have a minor effect on emissions and transport mode selection largely due to a reduction in the number of vehicles per household (Hachem, 2016). However, density is associated with other factors such as centrality, mixed land use, better transport choices, connectivity and accessibility.

Individual land-use characteristics are each limited to minor to moderate impacts on travel. However, these are synergistic and cumulative (Litman & Steele, 2024). This demonstrates these characteristics should be developed in conjunction to have a consequential impact on transport emissions.

4.7.2 VKT and emissions reduction potential in New Zealand

This research raises themes around how the resulting mode shift from appropriately considered urban form can reduce VKT. Chapman (2008) highlights that the factors discussed such as compactness, density, mixed land use and connectivity should be combined with comprehensive public transport systems and attractive active mode environments to reduce VKT.

A study from Germany (Holz-Rau & Scheiner, 2019) notes that the emissions benefits resulting from integrated transport and land-use planning should not be overestimated and should only be viewed as a secondary priority compared to other goals such as ensuring accessibility and a healthy and liveable environment. It is argued that historical transport growth is driven by social factors outside of land use. Chapman (2008) notes that, because many studies that discuss the potential for emissions reduction through urban form are from the USA, the potential for emissions reduction in New Zealand may be smaller due to the marginally lower rates of vehicle ownership. However, New Zealand's vehicle ownership rate is still one of the highest in the world, with 889 light vehicles per 1,000 people in 2021 (Ministry of Transport, 2021a). This raises considerations around whether the lower rates of vehicle ownership and use in Germany compared to the USA and New Zealand (Kahn Ribeiro et al., 2007) result in inauspicious conclusions produced by Holz-Rau and Scheiner. Regardless, this highlights the need for a focus on regions or areas within New Zealand that have a large potential for mode shift.

New Zealand exhibits potential for a reduction in transport emissions through changes in urban form that reduce VKT. The effects of a reduction in VKT through urban form is expected to provide emissions benefits and have a substantial influence on mode shift. Trips by car in urban areas generate the highest levels of transport congestion and emissions (Waka Kotahi NZ Transport Agency, 2019). With New Zealand's high rates of private vehicle ownership and use, mode shift from cars to public transport and active modes in addition to trip length reductions has the most potential to reduce transport emissions through integrated transport and land-use planning in New Zealand.

4.8 Propensity for uptake of active modes and public transport

Urban form and transport planning can be significant drivers in the uptake of sustainable transport modes. This section of the literature review examines the relationship between urban form, transport planning and propensity for the uptake of public and active transport.

4.8.1 Active mode uptake factors

4.8.1.1 Attitudes and perception

User perception is a key factor in influencing the uptake of alternative modes. A survey conducted in Hastings, New Zealand, found that people generally have a positive attitude towards walking and cycling but this did not translate to high levels of active transport or intentions to uptake active modes in the future (Muggeridge, 2012). The primary reason given for this was how people perceive active modes. Perceptions of risk and safety were significant barriers for cycling as well as for walking to a lesser extent. Other factors contributing to the discrepancy between attitude and uptake willingness included travel distance, lack of bicycle parking facilities, car culture and terrain features such as hills. This indicates that encouraging positive attitudes towards walking and cycling is not enough to increase uptake of these modes. Rather, positive attitudes should be supported by safe infrastructure and urban form that addresses negative perceptions of walking and cycling, travel distance and car culture. The survey also identified health/social benefits and reduced cost as factors that encouraged active travel. The negative effects of air pollution were not considered to be a direct driving factor in mode shift but rather a co-benefit.

4.8.1.2 Active mode infrastructure and education

The Activating Communities to Improve Vitality and Equality (ACTIVE) study undertaken by the Centre for Sustainable Cities New Zealand (Keall et al., 2015) aimed to determine whether a government initiative called the Model Communities Programme (MCP) shifted trips from motorised travel towards active modes. The MCP included cycling and walking infrastructure improvements and community education and was implemented in two New Zealand cities (New Plymouth and Hastings) selected due to their decreasing levels of active travel and compared to two control cities (Whanganui and Masterton) to determine the effects of the MCP. A proportional net increase of approximately 30% active trips was observed as a result of the MCP relative to the control cities. As the MCP involved both infrastructure improvements and community education, conclusions cannot be made on the extent of the individual effects of either on mode shift. However, the combination of both has proven to be effective in encouraging a shift towards active modes.

4.8.1.3 School trip factors

The propensity of students to make school trips by active modes is well researched in New Zealand relative to travel propensity for other purposes. It has been found that distance to school is the strongest predictor of active travel to school (Ikeda et al., 2018; Sandretto et al., 2020) and the perception of walking and cycling to school by adolescents differs by home-to-school distance (Mandic et al., 2022). Increased street connectivity was also related to an increase in active travel to school (Ikeda et al., 2018).

A seemingly counterintuitive finding is that dwelling density is negatively correlated with active travel to school. This may be related to evidence of an interaction effect between dwelling density and distance to school. A combination of low dwelling density and low distance to school may be positively related to active travel to school. However, it is likely that the effects of proximity to school may have overridden the effects of dwelling density in this study (Ikeda et al., 2018). Other concerns or barriers affecting active travel to school include school socio-economic status, topography and traffic safety (Sandretto et al., 2020).

Walking school buses are an effective method that has been adopted throughout New Zealand as a safe way to encourage parents to allow their children to walk to school (Smith et al., 2015). NZTA has multiple online resources to help parents initiate and coordinate the process (Waka Kotahi NZ Transport Agency, 2023e). However, limitations to this include the availability of parents to organise and accompany the students as well as unsafe driver behaviour around schools such as illegal parking at corners and on yellow lines (Hinckson, 2016).

Sandretto et al. (2020) found that schools tend to place decision making for active travel to school in the hands of the individual/family. This places the option of active travel to school outside of the school's scope of decision making and policies. While school leaders are willing to make decisions that improve the safety of students, they were hesitant to introduce initiatives that would affects parents' decision making as this could reduce the number of students at their school.

Cycle skills programmes are used widely across schools in New Zealand to help young people to build experience and confidence to ride in public spaces and undertake road cycling (Mandic et al., 2018). For example, Christchurch City Council has a Cycle Safe schools programme[13] that aligns with BikeReady curriculum developed by NZTA to teach students about bike maintenance, helmet fitting, basic cycling skills, road rules and road cycle safety.

Research shows young people agree that cycle skills programmes would likely increase their confidence cycling (Mandic et al., 2016). However, some studies suggest there are limitations to translation of increased confidence cycling to using cycling as a primary mode of transport to school. For example, after engaging

[13] https://ccc.govt.nz/transport/getting-around/schooltravel/resources-for-schools/cyclesafe

with a cycle skills programme, young people from Dunedin schools found they felt more comfortable cycling in parks and around playgrounds but few felt competent to cycle on roads or to school (Mandic et al., 2018).

In summary, research has highlighted several factors that influence active travel to school. Distance to school has been identified as a key predictor, with increased street connectivity being positively associated with active travel. Dwelling density, while initially appearing negatively correlated, may interact with distance to school in determining active travel behaviour. Initiatives like walking school buses and cycle skills programmes aim to promote active travel but face limitations in parental availability and translating confidence into regular use of cycling for commuting.

4.8.1.4 Pedestrian permeability, network connectivity and walkability

Key elements of urban form that effect walkability are pedestrian permeability, connections to destinations and density/compactness (Waka Kotahi NZ Transport Agency, 2024b). Best-practice urban design is therefore focused on compact urban form that features an interconnected street network with closely located employment, retail and neighbourhood centres, public transport connections and open spaces.

The function of roads and streets has traditionally been focused on the movement of people and goods, with the on-street activity function of roads and streets being secondary, if considered at all. To support walkability, pedestrians should be given a higher priority than other modes in places intended for people – civic spaces should prioritise people over general traffic.

A movement and place approach (also known as link and place) identifies function of roads/streets and corridors in relation to this wider network and applies the appropriate interventions. For example, in a street that has been identified as having a high place function, pedestrians should be given a higher priority/right of way than other modes. This approach can contribute to walkability through better consideration of the roles a street/road plays within the transport network (Waka Kotahi NZ Transport Agency, 2024b).

Similarly, the concept of complete streets prioritises the safety and mobility of all transport modes and users instead of the speed of cars and flow of traffic and has been adopted by cities around the world. Complete streets policies, plans and projects differ depending on the street/community. However, most examples include traffic calming, pedestrian safety features, safe cycling infrastructure and public transit infrastructure.

Other built environment factors can affect the uptake of walking. The Transport for London (2017) Healthy Streets framework provides evidence-based indicators for creating healthy, safe, attractive and inclusive streets that people want to walk and spend time in (Figure 4.13). This includes indicators relating to safety, noise, air quality, attractions, places to rest, social inclusion, ease of movement, shade and shelter.

Figure 4.13 Healthy Streets framework (reprinted from Transport for London, 2017, p. 12)

4.8.1.5 Trip distance and time

The distance that people are willing to walk or cycle largely depends on the individual, where they are going and how they will be getting there.

Walkable distances will depend on individuals' abilities and needs. The distance people are willing to walk is dependent on the level of service of walking facilities, including amenity, pedestrian delay, route directness and personal safety (Waka Kotahi NZ Transport Agency, 2024d). People tend not to walk longer than 30 minutes, and 90% of walking trips are less than 2 kilometres (Ministry of Transport, 2018).

It is often conventionally assumed that people will walk up to 800 metres to access public transport. However, people are generally willing to walk much further at both ends of their journeys – up to 1,200–1,300 metres. It was shown that high dwelling density up to 2 kilometres from a train station with a high service frequency has potential to generate significant walk-on patronage numbers (Ker & Ginn, 2003).

The average cycling trip (mean) distance in New Zealand is 4 kilometres (Ministry of Transport, 2023). To access public transport stations, cycling trip distance is typically dependent on accessibility and facilities provided at the station. A cycling catchment of <2.5 kilometres (<10 minutes) is applicable to all public transport stations with convenient access, amenities and services. This catchment extends to <5 kilometres (<20 minutes) for premium public transport stations with high-quality end-of-trip facilities. Trips up to 15 km to access public transport stations are limited and are typically only completed for a long-distance commute (Waka Kotahi NZ Transport Agency, 2024c).

4.8.2 Public transport uptake factors

4.8.2.1 Distance, frequency and accessibility

Similar to active modes, user perception is a significant factor in the usage of public transport and can be representative of users' behaviour and willingness to use public transport (Chowdhury & Ceder, 2013). Travellers must be confident in their ability to undertake a trip, and the perceived difficulty of this trip must be low. Factors such as personal safety, information, reliability of connections, waiting time and walking time all influence a user's confidence and perceived trip difficulty. If these attributes are delivered to a high level of quality, travellers' self-confidence and perceived controllability of their trips improves, increasing their willingness to use public transport.

NZTA has found that access to public transport services that are faster and arrive at a higher frequency attract people from a larger catchment than slower and less-frequent services (Waka Kotahi NZ Transport Agency, 2024d). For a low-frequency service, people are generally willing to walk <400 metres (<5 minutes). Public transport stops with a frequency of 15 minutes see a catchment of <800 metres (<10 minutes), and for rapid public transport stops or stations, this can be <1,200 metres (<15 minutes). These walking catchments represent a general distance that people are willing to walk and therefore will vary depending on the extent of factors that make an environment or route pedestrian friendly.

Surveys on train station walkable catchment areas in Auckland were undertaken to determine if an 800-metre radius represented the walking distance of passengers (Auckland Council, 2013). These showed that, for some stations, an 800-metre walking catchment radius is applicable. However, for others, this underestimates the actual walking distance. The survey for a train station in Papatoetoe showed a median walking distance of 1,200 metres. For train stations in New Lynn, Glen Innes and Mt Albert, more than 50% of respondents indicated that they walked further than 400 metres to arrive at a train station, and 15% walked further than 1,500 metres. Walking was the most significant mode to reach the train station for trips less than 2,000 metres.

Many of the most influential factors in the willingness of users to uptake public transport are related to their experience at public transport stations. Personal safety and security at stations is the most influential factor in the decision of travellers when using public transportation (Chowdhury & Ceder, 2013; Chowdhury et al., 2016).

In a survey undertaken at bus terminals in Auckland, it was found that the quality of the built environment in terms of safety had a significant effect on the number of pedestrians accessing a terminal (Chowdury et al., 2016). This included aspects such as clear sight distance of footpaths and stations being surrounded by commercial and residential land use, which increased feelings of personal safety through surveillance. This same study found that the primary purpose of public transport trips was to reach work, education or other suburbs. Errands and recreational activities were considered insignificant.

In 2022, Kāinga Ora launched the Easy Access and Sustainable Transport (EAST) research project to help understand how the wellbeing of public housing residents can be improved through transport (Thompson, 2022a). The survey received over 400 responses and contained questions under five main categories, including how customers travel, the barriers of using public transport, where they wanted/needed to travel to, their experiences of parking and overall customer wellbeing (Thompson, 2022b). The main recommendation was that Kāinga Ora should 'work with transport agencies and councils to improve public transport networks' frequency/coverage, active transport infrastructure and land use-transport integration, and ensure the development of local destinations to meet customer needs' (Thompson, 2022a, p. 4). Before reducing residential car parking, it highlighted that it is essential to enhance the frequency, coverage and accessibility of public and alternative transportation modes to ensure transport poverty is avoided. Providing alternative transport options (such as shared electric vehicles and shared electric bike racks) while councils increase public transport accessibility and reliability could help ease people into the transition of reducing private vehicle use (Thompson, 2022a).

The enhancement of active modes surrounding a public transport station can increase the uptake of active modes and public transport. For pedestrians, safety, accessibility, directness and amenity of the surrounding walking network are important for public transport facilities (Waka Kotahi NZ Transport Agency, 2024d).

4.8.2.2 Affordability

In February 2023, NZTA undertook a research project to examine how half-price fares have affected public transport patronage since the COVID-19 outbreaks began in New Zealand (Waka Kotahi NZ Transport Agency, 2023b).[14] According to the study, the introduction of half-price fares has led to an increase in patronage following the lows caused by the COVID-19 Delta and Omicron outbreak periods. About 7–8% of users reported that they would not have used public transportation had the half-price fares not been available. The research found that higher fuel prices and cost of living concerns have significantly contributed to higher passenger uptake of public transport. NZTA recommends that increasing public awareness of half-price public transport fares is vital to increasing patronage. Additionally, it was noted that the cost of public transportation has not been a barrier for people who do not regularly use it since 2019. However, common barriers included perceptions that public transport is not a realistic alternative due to its limited availability in their area or because it is not suitable for travelling over long distances or taking too long to reach their destination.

[14] The Community Connect programme is a targeted package introduced by the previous Labour Government aimed at making public transport more affordable by providing half-price fares for Community Services Card holders, people aged 24 and under and total mobility services and free fares for children aged 12 and under. The Coalition Government stopped funding free public transport for children and half-price fares for young people from May 2024 – see https://www.1news.co.nz/2024/03/09/govt-axes-kids-youth-public-transport-discounts-funding.

4.8.2.3 Land use and transport integration

Allowing intensified housing development in areas without sufficient public transport services increases congestion through an increased number of cars on roads, and restricting housing development in areas with good public transport services restricts their return on investment. To achieve favourable transport outcomes, transport demand generated by land use should therefore be aligned with transport provision (New Zealand Council for Infrastructure Development, 2016).

Transit-oriented development (TOD) is a type of urban development that optimises density and diversity (residential, business and open space) within a walking distance of public transport (Young, n.d.). A topic paper on TOD written by Stantec Urban Places found that, while public transport is a necessary pre-requisite to delivering TODs, substantial work must also be done to encourage broader social, economic and environmental outcomes in market development responses to the provision of public transport.

The intensification of Auckland over time has posed a challenge to achieving quality compact city ideals due to car dominance, which is more space intensive than public transport and active modes despite offering similar access (Auckland Transport, 2021). However, the gradual trend of growth shifting away from central locations into outer suburban areas with less-reliable public transport systems increases the likelihood of continued reliance on car travel. Additionally, geographic constraints by the Waitematā and Manukau Harbours create narrow transport and infrastructure networks into the city centre.

In 2019, Auckland Council declared a climate emergency, which has encouraged a shift towards public and active modes of transport. In the last decade, improved accessibility and diversification of transport modes within Auckland has led to less dependence on private vehicles. For example, between 2014 and 2019, 82% of New Zealand's total growth in public transport use occurred in Auckland (Ministry of Transport, 2019). Additionally, the expansion of new cycleways into existing networks has contributed to 8% annual growth in cyclists. Despite recent progress, the improved safety of alternatives (such as road cycling) and further investment in public transport and road infrastructure is necessary to ensure that all residents have access to efficient and reliable transportation options.

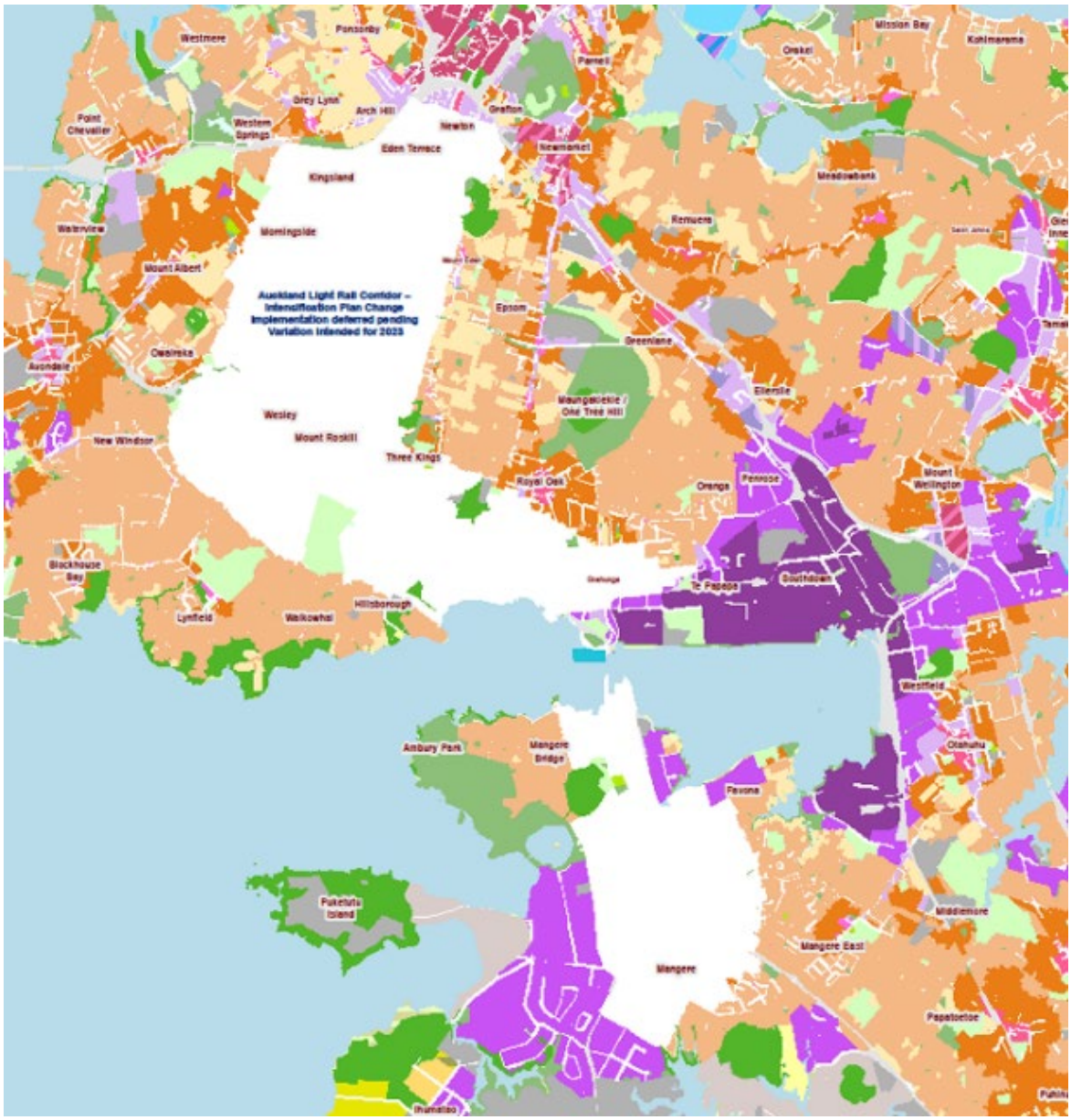
Many of the current and future public transport projects in Auckland do not align with land use as set in the Unitary Plan (New Zealand Council for Infrastructure Development, 2016). Examples include:

- development restrictions around major public transport stations
- growth being enabled away from public transport and near motorways
- future high-capacity corridors passing through growth-restricted land use
- future public transport corridor capacity being insufficient for the level of surrounding intensification.

Since this time, policy developments such as the NPS-UD have sought to intensify the areas surrounding key public transport stations and corridors. In Auckland, there was a carve-out for the Auckland Light Rail (ALR) City Centre to Māngere (Figure 4.14), marking a shift towards more integration between land use and transport planning. However, the ALR was cancelled by the Coalition Government in January 2024.[15]

[15] The Coalition Government issued a stop work notice to the project in January 2024 – see https://www.stuff.co.nz/national/301039545/government-pulls-the-pin-on-multibillion-dollar-auckland-light-rail-project.

Figure 4.14 ALR corridor (in white area) (reprinted from Auckland Council, 2022, p. 4)



Desirable transport outcomes are not solely dependent on the associated location of land use and transport provision. The Stonefields development in Auckland is an example of how further factors need to be considered in the integration of transport solutions with land use. Private vehicle use in Stonefields is among the highest in Auckland. Bus services in the area were not implemented at the same time as the properties in the development, leading to low patronage. In addition, there has been commentary that residents did not move to Stonefields for the public transport access but to drive shorter distances (New Zealand Council for Infrastructure Development, 2016). Therefore, it is important to understand what residents want and why when considering the integration of land use and transport provision.

4.8.3 Mode competitiveness and car alternatives

Having access to a car significantly reduces the likelihood of using an alternative transport mode (Wild & Woodward, 2018). However, if access to a car is to be reduced, it is important that alternatives are provided that allow similar functionality in terms of the type or nature of trips.

For high uptake of public transport, it is important to ensure that many of the factors outlined in section 4.8.2 are satisfied. However, the most essential aspect is that these factors need to be in place concurrently. Lunke et al. (2021) found that, even if one of either high-service frequency or direct routes/few transfers or efficient travel times is not in place, public transport usage and market share is significantly reduced.

E-bikes are a form of transport that allow more car-like trips to be made (Wild & Woodward, 2018). They enable actions that are more typical of car trips such as trip chaining – making trips with multiple different purposes and locations. E-bikes reduce exhaustion from long-distance travel and increase speed, making longer-distance trips quicker than by bicycle. Because of this, e-bikes make it easier to carry more items such as shopping or even children, and e-cyclists can fit in a more diverse range of trip types.

Compared to the 15 km maximum trip distance for an extremely limited number of bicycle trips (as detailed in section 4.8.1.5), e-bikes make travelling this same distance much more achievable. In New Zealand, a large proportion of people commuting on e-bikes regularly travel 15 km to work each way, and Auckland's Northwestern Cycleway was raised as an example of high-quality cycling infrastructure that allows the utilisation of e-bikes' increased speed capabilities (Wild & Woodward, 2018).

4.8.4 Impact of equity factors on sustainable transport mode uptake

There is a body of literature (Walker, 2021) that warns of the potential for transport decarbonisation goals (VKT reduction in particular) to further embed existing transport disadvantage and equity, notably:

- costs and disbenefits falling on those who are already disadvantaged
- benefits accruing to those who are already advantaged
- improvements failing to address inaccessibility or unmet need for particular user groups
- inappropriate infrastructure or services that do not consider actual barriers or needs of a community
- improvements inducing gentrification.

Individuals experience multiple factors that can limit their capacity to be sufficiently served by a transportation system (Litman, 2024). This demands an intersectional approach to transport provision that recognises that barriers to transport are not homogeneous and that there are often overlapping aspects of a person's identity that can compound barriers to transport (Arup & Urban Transport Group, 2022).

A study conducted by MRCagney for the Ministry of Transport (2020) on equity in Auckland's transport system identifies seven key groups that can disproportionately experience inequity – Māori, low-income people, women, LGBTTQI+ people, disabled people, older people and ethnic minority groups.

The equity issues experienced by these and other user groups generally fall under three interconnected categories, as defined by Litman (2024):

- Inclusivity – how transportation systems affect and serve those with special mobility needs.
- Affordability – how transportation systems affect those on limited income.
- Social justice – how transportation systems affect groups who are underserved and experience structural injustices.

These issues are concerned with the distribution of effects between those who have different abilities and needs (vertical equity). To help illustrate this, the three equity issues identified by Litman (2024) are explored in further detail below with examples of how these issues are experienced by different user groups in New Zealand.

Additionally, findings demonstrate the intersection between housing disadvantage and transport disadvantage. Transport disadvantage is when the transport system hinders individuals from accessing employment opportunities, educational resources and healthcare and can often lead to social exclusion.

Burke et al. (2014) researched the spatial concentration of lower-income renter households in Melbourne and Sydney and their connection with changes in transport opportunity. They found that outer-urban locations where lower-income households are increasingly renting often have significant transport disadvantage. MRCagney (2020) similarly found that, in Auckland, lower-income households are more likely to live in locations less well served by public transport.

4.8.4.1 Inclusivity

To be equitable, a transportation system must serve diverse users such as those identified by MRCagney (2020). These groups tend to rely on non-auto transport modes (Wang & Renne, 2023). Inclusivity in a transport system or lack thereof can be experienced very differently by different users. However, a common factor among all who experience inclusivity disadvantages is that they are not necessarily limited by their condition or circumstance but by society not accommodating them and restricting their ability to participate.

According to Litman (2024), accommodating a range of needs requires multi-modal planning to provide diverse travel options, priority parking and universal design to accommodate travellers with disabilities and other special needs. These users can also benefit from suitable housing in areas with high levels of accessibility and where most essential services are available within a short walk.

Additional support and assistance is required for those whose accessibility is limited by their physical condition. According to Walker (2021), physical accessibility barriers can include but are not limited to:

- long walking distances to access transport services
- physical infrastructure limiting accessibility such as steps at public transport stations
- insufficient seating on public transport for pregnant people, older people and people with chronic health conditions.

Non-physical accessibility barriers can be less obvious than physical barriers but may still have a large impact on one's ability to travel. Complex wayfinding information can be challenging for children, older people, speakers of English as a second language and people with vision, hearing or intellectual impairments. Chaotic, noisy, crowded environments such as busy streets or public transport can be triggering and even dangerous for neurodiverse people, very young people or older people (Walker, 2021).

Accessibility issues are not limited to public transport and active modes. Travelling by private vehicle can be difficult for people with health conditions or impairments. Operating a car can be difficult or impossible, and these conditions may impact their eligibility for a driver licence (Walker, 2021). Therefore, it is essential that a variety of viable transport modes are provided to enable a truly accessible transport system.

4.8.4.2 Affordability

Affordability refers to costs relative to incomes. In the context of transportation, it refers to people's ability to pay for transport services within their financial means (Litman, 2024).

Many trips such as commuting trips cannot be avoided. This can exacerbate issues for those who have limited transport options because they are restricted by their income. These unavoidable trips cause people to spend high proportions of their income on travel (Walker, 2021). According to Litman (2024), when households are unable to purchase healthy food, healthcare or education, the fundamental reason is often excessive housing and transportation expenses that leave insufficient money for these other essential goods and services.

Car ownership is also expensive. Those who cannot afford a vehicle will often go into debt to obtain and maintain a car, and high-interest repayments exacerbate this transport inequity (Walker, 2021). To mitigate the economic effects of car ownership, transport alternatives should be provided in areas where these are limited. This should be done in conjunction with prices that are competitive with cars for the service provided.

However, the costs of public transport, taxi and rideshare fees and the purchase/maintenance costs of owning a bike, e-bike or scooter can often be prohibitive (Walker, 2021). Options such as e-bikes have been highlighted as an excellent alternative to cars. However, these are unaffordable to low-income commuters who would benefit the most (Wild & Woodward, 2018).

Doran et al. (2022) examined disabled people's experiences of transport throughout New Zealand. Disabled people often need to make longer trips compared to non-disabled people, which increases the effort and cost of transportation. These challenges often lead to individuals skipping or reducing the number of trips they would like to make, thus reducing their access to opportunities. The Total Mobility Scheme is a funded programme by local and central government to assist people with disabilities to access appropriate transport to meet their daily needs and enhance their ability to participate in the community (Waka Kotahi NZ Transport Agency, 2023c). Although many disabled people appreciate the scheme's extra convenience and independence, Doran et al. discovered that many individuals do not use it due to cost and reliability issues.

In several cities worldwide, subsidies or social fares have been implemented to increase the use of public transport by low-income individuals (students, elderly and individuals facing poverty). Targeted subsidies can have a significant and positive effect on the benefited population by promoting public transport use, which encourages people to participate in more productive and leisure activities (Börjesson et al., 2020; Guzman & Hessel, 2022). However, subsidies are not only effective for addressing inequality but also create an additional benefit of increasing ridership and strengthening the financial stability of public transport systems (Guzman & Hessel, 2022).

Community Connect is a targeted package aimed at making public transport more affordable. Approximately 2.2 million people could benefit from Community Connect. From 1 May 2024, Community Connect provides half-price fares for Community Services Card holders and for total mobility services.

4.8.4.3 Social justice

Social justice considers structural inequities such as racism, ageism, sexism and classism (Martens, 2017; Romero-Lankao & Nobler, 2021). A century of car-centric planning has created a legacy of social injustice in many parts of the world, including destroyed and degraded communities and reduced access to social and economic opportunities for physically, economically and socially disadvantaged groups (Litman, 2024). Accessibility (or lack of) translates to social (health, education, recreation, social connection) and economic (employment) outcomes and therefore also has the ability to exacerbate existing physical and socio-economic disadvantages.

As an example, real or perceived safety can affect the propensity of certain people or groups to travel by various modes or routes or to certain destinations. According to Walker (2021), fears or concerns about road safety can take away from people's independence, discouraging them from driving or using active modes on certain routes. Concerns around the safety of active modes is especially impactful for children and elderly people. The mobility of certain people and groups can also be constrained by safety factors outside of accidental collisions, including bullying, harassment and violence. This can be especially critical for some ethnic minorities, women and LGBTTQI+ people (Walker, 2021).

Raerino et al. (2013) examined the connections between urban transport and the wellbeing of Māori. Generally, indigenous transport issues remain fairly under-researched and the links between transport and urban Māori health are complex and multi-dimensional. However, according to Raerino et al., transport is an environmental justice issue – injury statistics indicate inequities for Māori, who comprised 15% of the population but over 30% of road traffic fatalities in 2010.

The practicality of different travel options can also vary for different user groups, particularly with services such as public transport largely being designed to serve able-bodied, neuro-typical weekday commuters. This can exacerbate transport disadvantages, particularly for those with disabilities, those who access employment outside of typical commuting times or those who need to travel to multiple locations for their work and cannot do so within a reasonable amount of time. Those outside of the workforce, especially parents, can also experience difficulties with transporting their children or items without a private vehicle (Walker, 2021).

Raerino et al. (2013) contend that public transport systems have not been designed to meet the specific needs of urban Māori. Findings from their research suggest that Māori rely on their cars to access family, marae and cultural activities, which conflicts with their obligations as kaitiaki of the environment. Thus, restricting access to travel by car without providing alternative means of transport will likely impact negatively on Māori wellbeing.

People with disabilities experience a vast array of challenges in accessing the public transport system. Common barriers include the urban environment, terminals/stops, quality of footpath and public transport services, presentation of information and obstructions on footpaths (Park & Chowdhury, 2018). The common barrier cited by people with physical impairments and people with visual and aural impairments was bus drivers' attitude and unawareness of their needs. Intersectionality within disabled communities (ethnicity, age and gender) also needs to be considered to support disabled people who are marginalised in multiple different ways (Doran et al., 2022). Transportation systems also have the potential to correct and mitigate structural inequities through equitable transport planning and investment. Walker (2021) makes the following recommendations to address transport inequity while supporting the transition to a net-zero economy:

- 'Reprogramme' the transport system.
- Make sure the transition is tika (right and just).
- Reduce the overall need to travel.
- Make sure the costs and benefits fall in the right place.
- Kickstart the transition.

4.8.5 Impact of COVID-19 on transport mode share

Globally, COVID-19 has had a significant impact on travel behaviour. Internationally, a mode shift away from public transport has been observed (Abdullah et al., 2020). This is a result of private vehicles, cycling and walking having a low perceived risk of exposure to COVID-19, whereas public transport is perceived as having a much higher risk, which has had a significant effect on uptake (Shamshiripour et al., 2020). This difference has seen a mode shift from public transport to private vehicles and active modes (Abdullah et al., 2020).

These same trends have been observed in New Zealand. As of October 2022, public transport patronage in New Zealand had not yet recovered to pre-COVID-19 levels. An increase in active modes was observed, especially for recreational purposes, but this was mostly limited to lockdown periods. A reduction in traffic volumes was also observed during the pandemic. This led to a decline in the annual VKT observed in 2020 compared to previous years (Arachchige, 2021).

Many more people are also still working from home compared to pre-COVID-19 levels, and it appears that many will continue to do so in at least some capacity. However, as time goes on, people are increasingly returning to the office for more days of the week (Waka Kotahi NZ Transport Agency, 2022).

VKT reductions due to fewer trips taken are positive when considered in the context of reducing transport emissions, but this affects the viability of public transport.

5 Tool development exploration and findings

As briefly outlined in section 3.4, this research explored a methodology and concept design for a tool that can quantify the emissions impacts of spatial planning/changes in urban form.

This chapter documents this process and the key findings and recommendations on which the resulting tool development framework is based. The tool development framework is detailed in Appendix D.

5.1 Choosing an approach

The relationship between transport emissions and urban form is closely connected with travel demand to and from different points of interest that are unique to each town/city. Travel demand linked to a specific type of urban form is therefore not inherently determined. Instead, it is shaped dynamically by points of interest in the network, external factors and influences.

With this in mind, we explored two possible approaches to estimate the high-level emissions impacts of spatial planning/changes in urban form based on land use, demographics and transport supply. The usefulness of each approach hinges on the specific use case (a specific situation in which a product or service could potentially be used). The approaches are:

- for studying individual urban form – a multivariate regression model
- for studying region-wide urban form – a sketch planning tool.

The multivariate regression model approach would attempt to model emissions impacts based on elements of a specific urban form such as:

- the function of land use within the specific urban form (population, households)
- the land use within distance bands of the specific urban form (such as employment within 5 km of the specific urban form).

The benefit of this approach would be the simplicity of the model as the relationship between emissions impacts and urban form is linearly defined. The disadvantage of this approach is the rigidness of this type of model, which makes it difficult to set up the input variables for multiple zones/urban forms especially when multiple elements are dynamic.

The sketch planning tool approach would follow a similar method to that used by traditional four-stage transport models. In the past, strategic transport models have played a crucial role in evaluating the transport impacts of urban developments of various urban forms. Typically, spatial plans that comprise various urban forms are converted into land-use assumptions, which can then be modelled as different scenarios to assess their transport impacts. However, while these models are informed by a wealth of technical research, there are a few obstacles that prevent these models from being widely adopted throughout the planning process:

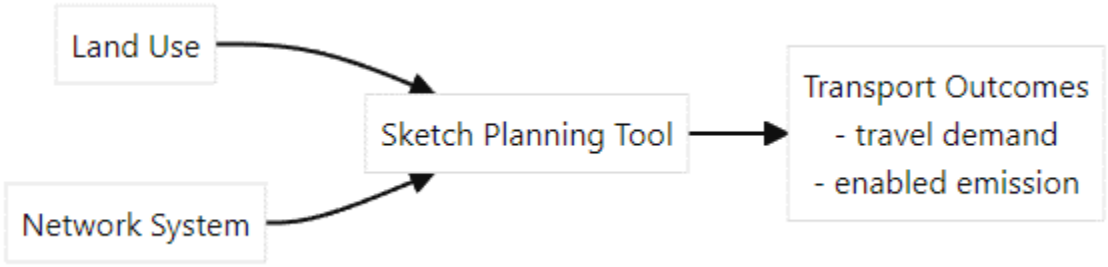
- Traditional four-stage transport models are vehicle centric and do not consider active modes.
- Traditional four-stage transport models typically require detailed input data to run that often is not available at the initial planning stage of a project.
- Due to the complexity of traditional transport four-stage models, scenarios are usually time consuming to set up and run.

After presenting the advantages and disadvantages of both approaches to the research project steering group, a sketch planning tool was chosen as the preferred approach to a tool development framework.

5.2 The sketch planning tool

Beca previously adapted a multi-modal sketch planning tool for the RLC FDS. This was used to estimate high-level travel demands and the associated emissions by mode in response to different land-use and network assumptions for spatial plans being explored as part of the development of the RLC FDS (Figure 6.1). With permission from Rotorua Lakes Council, our research focused on the implementation of the sketch planning tool to ascertain the key learnings and opportunities for improvement.

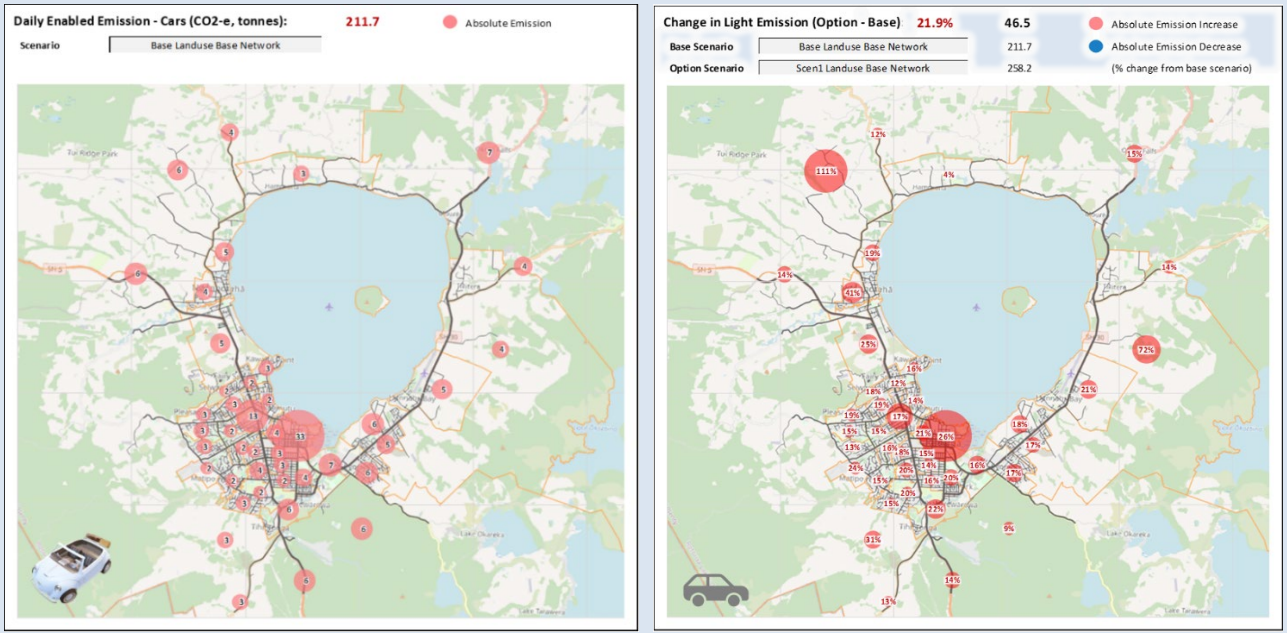
Figure 6.1 Sketch planning tool – conceptualisation of inputs and outputs



Case study: Sketch planning tool for the RLC FDS

To inform the RLC FDS, a sketch planning tool was calibrated to reflect high-level traffic conditions in Rotorua from 2018. The calibrated tool was then used to estimate the transport outcomes (travel demand and associated emissions) of different spatial plan scenarios comprising various land uses (such as intensification at specific locations) and network system changes (such as increased parking costs). The differences in transport outcomes between these scenarios were then used to support the decision-making process on a preferred spatial plan for the RLC FDS. As an example, Figure 5.2 shows the enabled emissions estimates for light vehicles for the calibrated base year (2018) compared to the future Ngongotahā growth scenario, which assumes housing development for the Ngongotahā region in the northwest corner shown in Figure 5.2.

Figure 5.2 Base year (2018) daily enabled emissions from light vehicles (left) and change in light vehicle emissions – sample outputs (right)

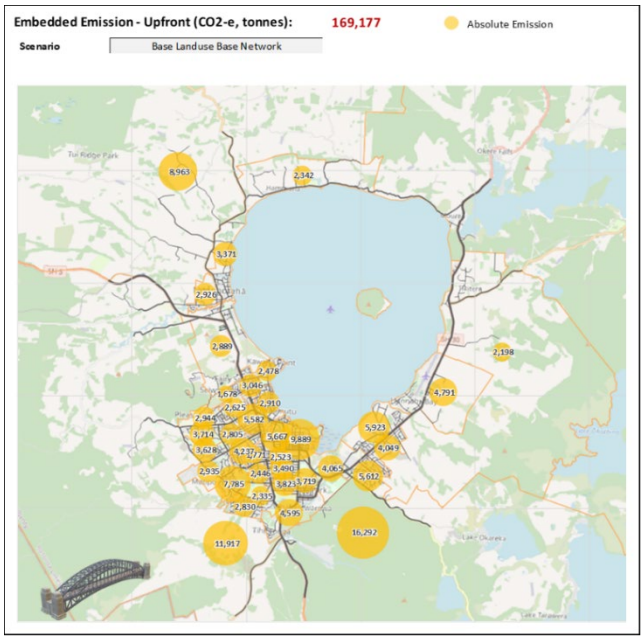


5.3 Exploration of embodied emissions

Our research also explored the potential to expand the sketch planning tool to estimate the embodied emissions (associated with the construction of assets) of horizontal infrastructure (footpaths, bus shelters, signage) required to support various urban forms.

This exercise utilised Rotorua Lakes Council's road assessment and maintenance (RAMM) data and the recently completed carbon footprint research from NZTA that assesses the embodied emissions from transport infrastructure (Tapper et al., 2024). This produces good estimates of upfront embodied emissions for the base year (2018) as the input data reasonably reflects reality (Figure 5.3).

Figure 5.3 Base year (2018) upfront embedded emissions



In a similar way to enabled emissions, the base year (2018) calibrated model can be applied to future spatial plan scenarios and used comparatively. However, this would be based on inaccurate assumptions, notably:

- the same relationship between urban form and horizontal infrastructure in the future state
- the same density of infrastructure across the same urban form type.

We therefore decided not to generate outputs for a future spatial plan scenario. There are multiple reasons that these assumptions do not hold:

- The density of horizontal infrastructure will vary largely on the specific spatial plan scenario. The methodology and guidelines for an expanded sketch planning tool outlined in Appendix D use a median asset density across urban forms of the same type for the base year to determine a relationship between assets and urban form that can be applied to future spatial plan scenarios. While this relationship could provide a general indication across the entire study area, the results showed that this method was inconsistent when looking at individual zones.
- Unlike the NZTA Vehicle Emissions Prediction Model (VEPM), which is used to apply current and future emissions factors to calculate enabled emissions, the embodied emissions factors in Tapper et al.'s (2024) research project capture a single point in time. Using these factors for future scenarios would therefore be inaccurate as material emissions factors change with time, which should be accounted for. This is discussed further in section 5.4.1.

- Assuming the asset to land use relationship remains the same in the future is regressive. Improvements to the latest design principles will influence the choice of asset type, materials, construction and quantity. Different assets will therefore be favoured in the future than what is observed. Assuming the same relationship will likely overestimate embodied emissions. This is discussed further in section 5.4.2.

In summary, the sketch planning tool has the potential to provide valuable insights into the relationship between transport emissions and urban form given the quality of input data that is available. In particular, the tool performs well when used comparatively between different spatial plan scenarios. While enabled emissions estimates were proven to produce reliable outputs, embodied emissions estimates can be improved by providing inputs that better represent the expected future state. The next section discusses the key learnings and recommendations to consider when developing and improving the tool.

5.4 Learnings and recommendations

The implementation of the sketch planning tool for the RLC FDS provides some valuable insights on the key principles of implementing and using such a comprehensive tool. These have been used to put together a robust set of recommendations on which we have based the tool development framework (detailed in Appendix D). These learnings and recommendations are summarised below.

5.4.1 Sustainability impact estimation

The sketch planning tool can be used to produce reasonable high-level estimates of transport outcomes in response to urban form. The tool is most suitable to use when comparing different scenarios during the early stages of a project where there is minimal detailed data.

The focus of this research has been on the impact of urban form on transport-related outcomes (such as travel demand and associated emissions). The feasibility of including other infrastructure such as vertical infrastructure (buildings) has not been considered. However, the scale of embodied emissions of vertical infrastructure will typically be much greater than the embodied emissions of horizontal infrastructure. For example, the embodied emissions associated with building an apartment building would likely be significant compared to the required transport infrastructure. The feasibility of a project is therefore more likely to be determined by the embodied emissions of vertical infrastructure. Expanding the tool to consider vertical infrastructure would therefore be beneficial.

The emissions profiles used by Tapper et al. (2024) only capture a single point in time. As time passes, emissions factors are expected to change due to anticipated improvements in material construction, transport and so on. While factors derived for the current state are suitable for the base year model, applying these to the future will be less accurate. The Project Emissions Estimation Tool (PEET) (Waka Kotahi NZ Transport Agency, 2023a) provides emissions estimates for historical, current and future years. The emissions profiles should therefore be adjusted to account for the changes predicted in PEET to be more suitable for testing future scenarios.

5.4.2 Model input creation

The sketch planning tool requires specific land-use data as the main input to determine travel demands and calculate the associated enabled emissions. The land-use information that is typically provided within future spatial plans (changes in dwelling yield/houses per hectare) is insufficient to use as an input to the sketch planning model and therefore requires manipulation into more meaningful data. Census information can be used to convert dwelling counts into an estimated number of households by comparing the census population and occupied dwelling counts with average household counts and applying this proportion to the future dwelling yield estimates. A typical assumption when building land-use scenarios is to assume that the

total population over the entire study area remains constant across all scenarios, in which case, the residential development within the spatial plan serves as a guide for distributing the population growth within the study area. It is essential to examine the shift in the population-to-household ratio between the base and future year scenarios, ensuring logical land-use inputs for the model. Stats NZ provides population and household projections at statistical area 2 level up to the year 2048, which can be used as the basis for total population within the study area.

In addition to land use, the tool uses employment as an input. Employment growth is typically expressed as vacant business/industrial land areas within spatial plans. These areas are typically outside of the residential development areas. In reality, to support development in residential areas, we would also expect organic employment growth within the development to service the growing population (retail, trades). It is therefore beneficial to assume a base residential employment rate for large residential growth areas to represent the expected organic employment growth within the area. Future-year employment projections are not available from Stats NZ and therefore it is recommended to calculate the likely employment rate (percentage of the population that will likely be working or actively looking for work) based on census data about employment and the future population projections within the study area.

Similar to employment rates, it is essential to check the participation rate for school rolls between the base and future year scenarios. In some cases, population projection by age can be used to adjust the participation rate for future scenarios – for example, a reduction in percentage of school-aged population in the projected population would support the lowering of the participation rate for estimating future school rolls.

The proposed sketch planning tool utilises the One Network Road Classification (ONRC) GIS dataset from NZTA, which contains nation-wide roading information and classifications, as the basis for deriving accessibility across different modes. While the network dataset is nation-wide, it can be inconsistent and was not created for the purpose of accessibility assessments – for example, the polylines inside the GIS layer do not form a connected network. Therefore, it is important to run preliminary analysis and pre-process the data to ensure it is fit for the accessibility assessment. This pre-processing will likely be specific to the study area and may also need to be adjusted with the upcoming upgrade of the ONRC to the One Network Framework.

To estimate the horizontal infrastructure required to support future developments, the relationship between infrastructure and urban form is assumed to be the same between the future and current state (low-density residential will require the same number of each asset type in the future as it does currently). This choice was influenced largely by the data available at the time of this research. While infrastructure data is reasonable for the current state, there is minimal quantitative insight into how infrastructure needs might change in the future. Applying the same relationship as the current state to future scenarios is therefore slightly regressive as it does not consider improvements to the latest design principles and standards that future developments will be built to adhere to. The resulting estimations would be biased towards overestimating historical assets, which would typically lack efficiency in comparison to future designs.

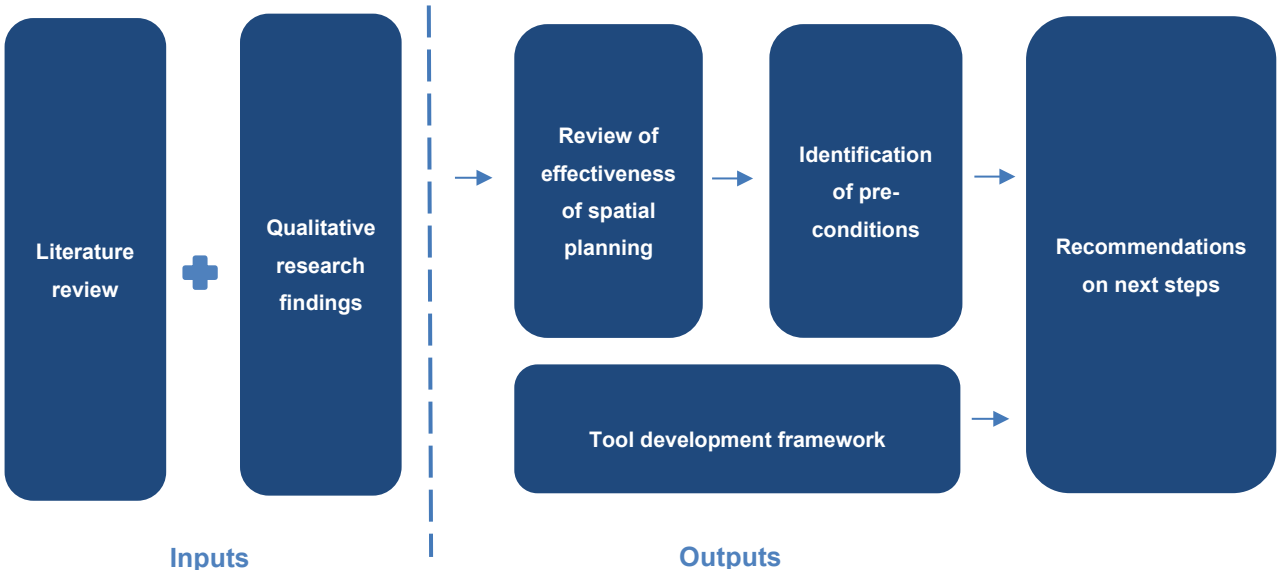
Finally, the tool does not consider site differences such as terrain when building relationships between infrastructure and land use. Terrain would likely influence the quantity of different asset types within an area – for example, more retaining walls would be required for residential developments in hilly terrain. Given that asset requirements for new developments tend to be influenced by multiple factors, attempting to capture this relationship with a quantitative model would be difficult. In addition, adding more factors may risk making the tool too complicated without significant improvements to the accuracy.

6 Review of effectiveness of spatial planning and initial recommendations on pre-conditions

This chapter brings together the findings from the literature review, interviews and FranklyAI conversational tool to provide:

- a review of the effectiveness of spatial planning and change in urban form as an intervention for sustainable mobility
- the pre-conditions required for successful integrated planning of transport and urban form to deliver sustainable transport outcomes (Figure 6.1).

Figure 6.1 Inputs and outputs of this component of the research



Important things to note about the necessary pre-conditions and recommendations

A key finding of this research is the need for a coordinated systems approach to derive sustainable transport outcomes through integrated planning of transport and urban form. Therefore, the themes, pre-conditions and subsequent recommendations should not be considered in isolation as there are many interdependencies and synergies between them. The recommendations have been developed for transport agencies (NZTA and local government planners and funders). However, individual agencies do not have all the levers to achieve the pre-conditions identified in this research. A joined-up and collaborative approach is needed between central and local government, iwi and developers as each have an important and unique role to play in the system.

In addition, the pre-conditions are highly context dependent – what is necessary in one region/city/town may not be necessary somewhere else. Similarly, integrated transport and land-use planning can occur at a range of scales (single site/dwelling, precinct, region) and some pre-conditions may not be necessary at all of them. We have identified any possible variances where they are known. As a general principle, a nuanced and place-based approach is needed to integrated planning of transport and urban form that recognises the unique characteristics, challenges and opportunities of places and projects. This requires meaningful engagement with mana whenua, local practitioners and communities (listening, learning and taking their knowledge and experiences into account). Meaningful engagement with communities also helps to ensure that changes meet the diverse needs of users the infrastructure or service is meant to benefit and do not perpetuate existing transport inequities.

6.1 Review of the effectiveness of spatial planning and change in urban form in achieving sustainable mobility

Taken together, the findings from the literature review, interviews and FranklyAI conversations suggest that spatial planning and change in urban form is an effective method for achieving sustainable transport outcomes in New Zealand when combined with comprehensive public transport systems and attractive active mode environments to reduce VKT.

Light vehicles are responsible for a large proportion of our transport emissions, and therefore trip length reductions through integrated transport and land-use planning have significant potential to reduce our transport emissions. According to the literature, VKT reductions through changes in urban form (density, mix) are also expected to improve accessibility and support healthier, more liveable urban environments.

FranklyAI identified a number of barriers to mode shift regardless of how well integrated transport is with housing and urban development, which highlights the need for a number of other factors or pre-conditions to be in place in order to shift people's travel behaviour and achieve wider benefits such as increased access and equity.

As the relationship between transport emissions and urban form is complex and dynamic, we recommend using models similar to the one proposed in the tool development framework detailed in Appendix D.

6.2 Required pre-conditions

Appendix C of this report synthesised the key findings from the interviews and FranklyAI conversational tool. These findings, along with our learnings from the literature review, have been used to identify the necessary pre-conditions for integrated planning of transport and urban form to enable behaviour change and mitigate/address adverse conditions relating to New Zealand's prevailing urban form, our regulatory, policy and funding framework, our culture and our socio-economic preferences. These are structured under four key themes:

- Transport infrastructure, services, attitudes and preferences.
- Housing market, attitudes and preferences.
- Social infrastructure and local amenities.
- Legislation, regulations, funding and operations.

As identified in the literature review, there is a paucity of studies that evaluate the emissions impacts of spatial planning in New Zealand. Therefore, the pre-conditions identified below are hypothesised based on this research and require further investigation and testing.

For clarity, a pre-condition is defined in the Oxford dictionary as 'something that must happen or exist before something else can exist or be done'.[16] In this case, a pre-condition refers to what must exist in order for integrated planning of transport and urban form to deliver sustainable transport outcomes in New Zealand.

6.2.1 Transport infrastructure, services, attitudes and preferences

As summarised in the literature review, for integrated planning of transport and land use to successfully reduce emissions and achieve broader social, economic and environmental outcomes, people must be inclined to change their travel behaviour in favour of more sustainable transport modes.

[16] https://www.oxfordlearnersdictionaries.com/definition/english/precondition

To achieve this, this research has identified a number of necessary pre-conditions within the New Zealand context relating to both the transport offering (access and design) in a given area and people's transport preferences and attitudes (Table 6.1). These two aspects of transport demand interact and inform people's choices about how, where and when they travel.

Table 6.1 Pre-conditions and detail for transport infrastructure, services, attitudes and preferences

Pre-condition	Detail (what is required in New Zealand)
People have access to a range of viable, sustainable transport options (public transport, walking and cycling) regardless of their social identity and where they live, work, learn and play.	• A spatial planning system that enables long-term investment decisions and collaboration between actors and agencies. • The public sector works closely with developers to ensure housing and urban developments are integrated with a range of viable, sustainable transport options. • The public sector works closely with developers to ensure sustainable transport options are established in greenfield areas before the construction of new housing is completed. • Car-sharing provisions (parking space, vehicles) are included and incentivised in new housing and urban developments. • People on low incomes (such as Community Services Card holders) receive sustainable transport subsidies (for public transport and e-bike, scooter, car and cycle-sharing schemes). • Sustainable transport corridors, including designated busways and cycleways, are identified and protected in long-term regional spatial strategies.
Public transport services are reliable, efficient, affordable and safe, regardless of trip origin and destination.	• Public transport services meet demand. • Public transport information systems provide accessible public transport information in real time. • Public transport is broadly perceived to be efficient, frequent, reliable and affordable.
Footpaths, walkways and cycleways provide safe, efficient journeys for people of all ages and abilities to enjoy.	• User safety and access are at the forefront of footpath, walkway and cycleway design. • Vehicles are diverted away from and/or vehicle speed limits reduced in places with a high place function or areas of high pedestrian activity such as main shopping streets and near schools. • Cities/towns provide continuous, separated cycle networks. • Pedestrian permeability is provided from the outset in new subdivisions. • Complete streets are provided in places with a high place function or areas of high pedestrian activity such as main shopping streets and near schools. • Walking and cycling are broadly perceived to be safe, efficient, healthy and enjoyable transport options.

6.2.2 Housing market, attitudes and preferences

For integrated planning of transport and land use to successfully reduce emissions and achieve broader social, economic and environmental outcomes, the housing market must deliver quality, medium/high-density housing in locations that are well serviced by viable, sustainable transport options, social infrastructure and local amenities.

People choose to live in these dwellings and locations because of the quality, amenity and lifestyle offering.

To achieve this, this research has identified several necessary pre-conditions relating to the housing market and people's housing attitudes and preferences (Table 6.2). This reflects the findings of this research that,

while developers build what they think will sell (the Kiwi quarter-acre dream), there are other market factors at play (legislation, policy) that influence the type and location of housing that is brought to market. The findings also suggest that the number of terraced houses and walk-ups is growing, and attributes such as proximity to social infrastructure and amenities and higher design and build quality could help draw more people to higher-density living. This highlights the need to shift away from the notion that the market is demand-led towards more innovation in the housing sector.

Table 6.2 Pre-conditions and detail for housing market, attitudes and preferences

Pre-condition	Detail (what is required in New Zealand)
The housing market delivers a range of housing typologies at a range of price points in locations that are well serviced by viable, sustainable transport options, social infrastructure and local amenities.	• Statutory plans/strategies provide for a range of housing typologies in locations that are well serviced by sustainable transport, social infrastructure and local amenities. • Statutory plans/strategies enable density commensurate with access (via sustainable transport) to jobs, social infrastructure and local amenities. • The volume and type of housing available on the market (both rent and buy) meets demand (evidenced by population data, sales data and housing preferences). • The resource management system limits bad trade-offs such as building more houses at the cost of quality housing and neighbourhoods.
Māori housing needs, aspirations and preferences.	• Regional spatial strategies identify the areas where mana whenua would like to live, develop (for their iwi) and/or protect. • Mana whenua have opportunities to deliver affordable housing that meets the needs of iwi, hapū and whānau.

High-density and medium-density housing is high quality and meets the diverse needs of New Zealand's population, communities and households.	• Initiatives are implemented to improve the quality of urban design – for example:
	  ○ urban design guidelines should be prepared for each region and must reflect cultural identity, narratives and preferences
	  ○ subsidies or development bonuses for good urban design
	  ○ upskilling in the built environment sector.
	• Developers are incentivised to deliver a range of quality high/medium-density and mixed-use typologies in locations that are well serviced by sustainable transport, social infrastructure and local amenities.

A range of people and households desire to live in high-density and medium-density housing because of its quality, amenity and lifestyle offering.	• The public sector partners with iwi, developers and communities to deliver models of density done well. • Examples of density done well are showcased and promoted by central and local government through storytelling and a diversity of lived experiences.

6.2.3 Social infrastructure and local amenities

For integrated planning of transport and land use to successfully reduce emissions and achieve broader social, economic and environmental outcomes, it must include consideration of social infrastructure (schools, GPs, counselling services) and local amenities (shops, private services, cafés, restaurants).

As an example, if people live in an apartment outside a bus rapid transit stop on a direct route to the CBD but must wait 30 minutes and take two buses to visit the doctor or a supermarket, they will either:

- drive or be a passenger in a vehicle – if they don't own a car, taking a taxi or rideshare has economic disbenefits

- take the two buses – which has social and economic disbenefits due to stress, the associated costs, the time taken to get from A to B and accounting for any delays or cancelled services
- not take the trip – which has more significant social and economic disbenefits.

In any scenario, the emissions reductions and/or broader outcomes of the bus rapid transit route are diminished. It is also unlikely to remove the need for people to own cars and therefore people will continue to desire car parks (reducing the housing density that is possible on a given site) and/or park on the street, which has disbenefits for safety and amenity. These scenarios also have a particularly severe impact on people with disabilities.

On the other hand, provision of social infrastructure and local amenities in place can reduce VKT and help to address transport inequities through improving access in places with high levels of transport disadvantage.

To mitigate adverse effects, reduce emissions and achieve broader strategic outcomes such as equity, this research has identified a pre-condition for integrated planning (Table 6.3).

Table 6.3 Pre-condition and detail for social infrastructure and local amenities

Pre-condition	Detail (what is required in New Zealand)
People can easily access social infrastructure and local amenities via public transport, walking or cycling regardless of their social identity and where they live, work, learn and play.	• Regional spatial strategies focus on the provision of social infrastructure and local amenities in place and provide good access to these via sustainable modes. • There is a high threshold for sacrificing social infrastructure and local amenities in greenfield developments at the expense of more dwellings – the creation and/or preservation of essential community services and neighbourhood amenities is prioritised over increasing the number of dwellings in a development. • Place-based strategies that go beyond transport/urban form, taking into account the lifestyles of residents such as public green space provision. • Masterplans are required for urban developments of 5 ha and above (for example) and must provide a minimum amount of social infrastructure and local amenities. • Developers (including councils, community housing providers, Kāinga Ora and iwi) work closely with councils and public transport operators to ensure housing is linked with social infrastructure and local amenities.

6.2.4 Legislation, regulation, funding and operations

For integrated planning of transport and land use to successfully reduce emissions and achieve broader social, economic and environmental outcomes, legislation, regulation, funding and operations must work together to enable this.

The pre-conditions in Table 6.4 describe the rules, regulations, funding mechanisms and operational conditions that this research has identified as necessary to harness the emissions reductions and broader strategic outcomes potential of integrated planning in New Zealand. The nature of many transport agencies' work means that there are many opportunities to partner and collaborate with other groups and organisations, including other central government agencies, in the creation of legislation, regulation or funding and operational opportunities.

Table 6.4 Pre-conditions and detail for legislation, regulation, funding and operations

Pre-condition	Detail (what is required in New Zealand)
Policy, planning and regulation (central and local) enables integration of transport and urban form.	• Density is enabled in locations that that are well serviced by sustainable transport, social infrastructure and local amenities. • A minimum amount/area of mixed-use zoning is provided in areas/walkable catchments commensurate with the population. • Green spaces (including urban forests, community gardens, parks and reserves) are provided in dense areas (both existing or planned).
Roads are improved for sustainable transport as part of road maintenance and renewals.	• Roads are improved for walking and cycling as part of road maintenance and renewals (such as reallocation of road space). • There is a designated fund that can be accessed by local authorities strictly for transport projects and on a faster and more agile basis. • Kāinga Ora can access capex and opex funding for transport as part of its housing and urban development function. • Local authorities can access capex and opex funding for public transport. • Public spending (central and local government) on active transport is transparent and clearly communicated to the public.
Funding frameworks recognise and value the broad benefits of urban integration.	• The business case process is agile – able to respond and adjust to contextual changes during its development. • The business case process recognises and values broader, long-term social, economic and environmental outcomes and wellbeing benefits. • There is a mechanism/tool available to quantify the broader long-term social, economic and environmental outcomes and wellbeing benefits of urban integration. • Traffic growth is delinked from economic growth. • Funding frameworks strongly incentivise territorial authorities' choices in favour of urban integration outcomes.
Urban integration outcomes are carried through the life cycle of projects.	• There are strong links between research, communication and engagement teams, investment teams, asset managers and so on. • Funding is linked to agreed outcomes developed with stakeholders and communities.

7 Conclusion and recommendations

This chapter makes a number of recommendations on next steps for central and local government transport agencies to help achieve the necessary pre-conditions for successful integrated planning of transport and urban form in New Zealand. They draw from the findings of the literature review, qualitative findings and necessary pre-conditions.

Central and local government transport agencies regulate, plan and fund the transport system in New Zealand. While regulation and funding are important aspects of integrated transport and land-use planning, individual transport agencies do not have all the levers to achieve the necessary pre-conditions for successful transport and land-use integration identified in this research. This underlines the need for a coordinated and collaborative systems approach to transport and land-use integration. It also highlights an opportunity for transport agencies to define and develop their individual role in facilitating integrated planning outcomes.

A key finding of this research is the need for a combination of many elements and measures to enable effective urban integration in New Zealand. There are many different areas that central and local transport agencies could focus on. Clearly defining an agency's individual role in integrated transport and land-use planning will help it identify and prioritise areas for further investigation and/or improvement.

To assist with this process, we have explored the greater role that central and local government transport agencies could play in achieving the necessary pre-conditions for effective integrated planning of transport and urban form in New Zealand and made a series of recommendations using the results of this research to help inspire and guide their thinking.

Influence

Central and local government transport agencies have the advantage of having many interfaces with the public and private sectors and communities that it can leverage to influence the system and cultural/behavioural changes needed to achieve the pre-conditions identified in this research. In particular, transport agencies could play a larger role in educating, advocating and promoting successful integrated transport and land-use projects to the general public. Transport agencies could also utilise investment levers to fund projects and programmes that foster integrated transport and land-use planning.

This research makes these recommendations for transport agencies:

- Consider working with the other agencies, sectors (including the private sector) and communities to develop a narrative that speaks to the bigger picture and broader outcomes being sought through integrated planning and encourages people and practitioners to embrace change.
- Consider transport and land-use integration as part of assessments of options for investment decisions for transport projects and large-scale residential development projects (multi-criteria analysis).
- Explore opportunities to increase public education through storytelling and showcasing and promoting a variety of user experiences such as:
  - integrated transport and land-use projects that have successfully shifted people's transport choices
  - sustainable transport infrastructure projects (walkways, cycleways and mass rapid transit, including busways) that have successfully shifted people's transport choices
  - quality high-density and medium-density developments done well that are integrated with sustainable transport options to help sell the lifestyle offering.
- Continue to work with central government agencies to ensure that mass rapid transit corridors (including designated busways) and cycleways are included in regional spatial strategies.

- Consider working with central government to expand and strengthen the Community Connect package – for example, widening the eligibility criteria and including discounts on other sustainable transport options (such as e-bike, scooter, car and cycle-sharing schemes).
- Investigate minimum requirements for social infrastructure and local amenities in place commensurate with access (via sustainable transport modes), population and community composition.

Facilitation

Central and local government transport agencies could facilitate some of the pre-conditions identified in this research through their funding, regulatory and operational functions by making it easier and/or more viable for transport and land-use integration projects to reduce transport emissions and achieve broader sustainability outcomes.

As a first step, this research makes these recommendations for transport agencies to consider in working with other central and local government agencies:

- Review their investment decision-making framework to ensure that land-use and transport integration outcomes are provided for in policy, guidelines, process and tools.
- Review funding frameworks for consistency with the identified pre-conditions and consider:
  - a funding mechanism that can be used strictly for transport projects (not for new pipes or road upgrades disguised as transport projects) and on a faster, more agile basis
  - allowing councils and Kāinga Ora to access capex and opex funding for low-emissions transport investment
  - a requirement for roads to be improved for walking and cycling as part of road maintenance and renewals (such as reallocation of road space).
- Investigate how transport funding and policy can support housing development in locations that are well connected by public and active transport and are close to town centres and amenities/services – for example, increasing funding assistance rates to strongly incentivise territorial authorities' choices.
- Investigate a requirement for road controlling authorities to reduce speeds along state highways to support sustainable urban form outcomes.
- Review business case process and explore:
  - opportunities to make it more agile throughout the project life cycle
  - opportunities for it to recognise and value broader long-term social, economic and environmental outcomes and wellbeing benefits – for example, this could be improved to provide for outcomes and benefits that are not as easily quantified such as health, equity and social wellbeing.
- Review and explore opportunities to improve links between research, asset managers, communication and engagement, and investment teams across national and local government planning organisations. This could support more evidence-based decision making and ensure that shared outcomes are being carried through the project life cycle.
- Review public transport information systems (consistency in messaging, timeliness and accessibility) and explore opportunities to improve these in guidelines and standards.
- Continue to evaluate community engagement processes to identify areas for improvement. This should include consideration of representation from different groups in the community and the degree to which community goals and aspirations have been realised.
- Utilise a tool (as investigated in this research) that can dynamically respond to changes in land use and network systems to evaluate the emissions impacts of proposed investments and investigate how this could be incorporated in the investment decision-making framework.

Leadership

Central and local government transport agencies are system leaders for transport. Therefore, many organisations (both public and private) look to them for guidance on how to execute transport projects. This presents many opportunities for transport agencies to model the behaviours, principles and processes necessary for transport and land-use integration projects to reduce transport emissions and achieve broader sustainability outcomes.

As a first step, this research makes these recommendations for consideration by central and local government transport agencies:

- Explore opportunities to partner with housing developers, mana whenua and communities to deliver and model integrated transport and land-use projects.
- Consider developing a framework, checklist and/or guidance document for delivering integrated transport and land-use projects at a variety of scales. This should speak the language of road controlling authorities, developers (including iwi), mana whenua and communities.
- Investigate:
    - Māori needs, preferences and aspirations for housing and communities
    - Pasifika needs, preferences and aspirations for housing and communities
    - barriers and enablers to developers offering car-sharing schemes in new housing developments
    - innovative approaches to meeting public transport demand such as on-demand shared services and feeder services
    - barriers and enablers to establishing sustainable transport infrastructure, services, social infrastructure and amenities in greenfield developments before new housing
    - a tool to quantify the broader long-term social, economic and environmental outcomes and wellbeing benefits of urban integration
    - New Zealand's cultural housing and transport preferences and how to shift these towards more low-carbon lifestyle preferences
    - the factors behind the increase in terraced housing and walk-ups in Auckland and Wellington.

Collaboration

The nature of the work of central and local government transport agencies means they have many opportunities to partner and collaborate with mana whenua, businesses, communities and other central/local government agencies. Working together will be critical to achieving the system and cultural/behavioural changes that are necessary for transport and land-use integration projects to reduce transport emissions and achieve broader sustainability outcomes.

As a first step, this research makes these recommendations for transport agencies:

- Explore opportunities for greater knowledge sharing and collaboration to uplift the capability of other agencies and sectors (including the private sector) – for example, some organisations may want to consider establishing a regular forum or community of practice.
- Consider if/how they could work with developers to ensure new housing and urban developments are integrated with a range of viable, sustainable transport options and provide a range of housing typologies.
- Continue to work with councils to provide continuous, separated cycle networks and safe, permeable pedestrian networks. Alongside central government agencies, councils and/or Kāinga Ora, investigate:

- how measures could be implemented to improve urban design – for example, urban design guidelines could be incorporated into the National Planning Framework and/or future resource management plans via assessment criteria for activities requiring resource consent
- a tool to help assess public transport demand (including latent demand) to support public transport investment, services and reliability
- a tool to help assess the appropriate level of housing density commensurate with access (via sustainable transport) to jobs, social infrastructure and local amenities as a means of ensuring statutory planning processes enable increased residential density in areas with good access to jobs, social infrastructure and local amenities via sustainable transport and limit trade-offs
- a tool to assess adequate access (via sustainable transport) to social infrastructure and local amenities, which could be used to inform mixed-use zoning, social infrastructure investment, green space strategies and town centre improvements and limit bad trade-offs (such as simply building more houses at the cost of including social infrastructure and local amenities such as green spaces).

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Appendix A: Interview questions

Theme	Lead question	Follow-up questions (and additional follow ups in blue)
Defining urban form in Aotearoa New Zealand	What do you think are the biggest issues and opportunities relating to the sustainability of Aotearoa New Zealand's current urban form?	How would you describe/define/measure the different urban form typologies across Aotearoa New Zealand?
		How do these different typologies impact environmental sustainability? Do you have any examples/evidence of this in New Zealand?
		How do these different typologies impact broader transport outcomes – namely inclusive access, healthy and safe people, economic prosperity, resilience and security?
		How has traditional urban form in Aotearoa New Zealand impacted socio-economic settlement patterns and access to opportunities?
		Compact urban form typologies such as 20-minute neighbourhoods and low-traffic neighbourhoods are gaining momentum overseas. What are the barriers to delivering these in Aotearoa New Zealand? What conditions are needed to support/enable the delivery of them?
Residential density in Aotearoa New Zealand	What are the biggest barriers and enablers to delivering higher-density housing in Aotearoa New Zealand?	Do you think Aotearoa New Zealand's current policy framework (NPS-UD, RMA amendment, RM reforms) will achieve the desired residential density outcomes for our urban areas? Why/why not?
		What are the barriers to delivering higher-density housing in Aotearoa New Zealand (medium/high-density housing)?
		What conditions are needed to support/enable the delivery of higher-density housing in existing urban areas?
		What conditions are needed to support/enable the delivery of higher-density housing in greenfield areas (with good access to education, employment, shops, services and open space)?
		How can increased residential density in Aotearoa New Zealand deliver broader health, wellbeing and equity outcomes? Do you have any examples of a higher-density development in Aotearoa New Zealand achieving these?
Housing preferences	How do you think Kiwis' housing preferences shape our towns and cities?	Where do Kiwis generally prefer to live (inner city, inner suburbs, outer suburbs, rural)? Do you have any evidence/data that suggests people's location preferences have changed or are changing?
		How do these location preferences relate to access? Do people prefer to live in proximity to their employment, shops or open space and recreation?
		What residential typologies do Kiwis generally prefer to live in (stand-alone, terraced housing, apartments). Do you have any evidence/data that suggests people's housing preferences have changed or are changing?
		How much does the market provide for these preferences (where/what residential development is occurring and why)?
		Do you think Kiwis are more likely to trade off their location preference for their typology preferences or vice versa? Why do you think this is? Do you have any examples/evidence of this?
		What are Kiwis' understanding of and appetite for mixed-use neighbourhoods? Do you have any examples/evidence of this?
		What amenities do people want in their neighbourhood?

Theme	Lead question	Follow-up questions (and additional follow ups in blue)
COVID-19 impacts on housing and transport preferences	How has COVID-19 impacted people's housing and transport choices?	How has COVID-19 and the shift to more flexible working impacted people's housing preferences? Do you have any examples or evidence of this changing?
		How has COVID-19 and the shift to more flexible working impacted people's travel choices and behaviour? Do you have any examples or evidence of this changing?
Transport planning	What are the barriers and enablers to transport planning achieving good urban integration outcomes?	What is the priority for transport policies/projects/investments to achieve urban integration outcomes in contrast to other priority trade-offs? Do you have any examples/evidence of this?
		What opportunities are there in Aotearoa New Zealand for transport to realise the benefits of increasing urban density? What conditions are needed to achieve this?
		What are the barriers to providing an efficient, frequent and inclusive public transport system (one that services outer suburbs, low socio-economic areas and provides for off-peak travel and trip chaining)?
Delivering successful transport and land-use planning	What pre-conditions are needed in Aotearoa New Zealand's towns and cities to achieve urban integration?	How well are proposed urban development projects in Aotearoa New Zealand taking into account the availability of sustainable transport options? Do you have any examples/evidence of this?
		How well are proposed urban development projects creating demand for sustainable transport? Do you have any examples/evidence of this?
		What is the priority for new urban development projects to achieve urban integration outcomes in contrast to other priority trade-offs? Do you have any examples/evidence of this?
		Do you have any examples of an urban integration project that has successfully shifted people's travel behaviour to more sustainable transport modes? If so, what were the critical elements of the project that made it successful?
		How well are proposed urban development projects taking into account the availability of social and community infrastructure? Are they being planned to encourage sustainable travel to these destinations? Do you have any examples/evidence of this?
		How well are proposed urban development projects taking into account proximity to town centres? Are they being planned to encourage sustainable travel to these destinations? Do you have any examples/evidence of this?
		How well are building heights and dense urban form in Aotearoa New Zealand's tier 1 urban environments being optimised to realise the land transport benefits of intensification? Do you have any examples/evidence of this?
Broader outcomes	How can urban integration deliver broader health, wellbeing and equity outcomes?	How can urban integration achieve Māori aspirations? Do you have any examples or evidence of this?
		How can urban integration achieve better health, wellbeing and equity outcomes for Māori? Do you have any examples or evidence of this?
Property development	What do developers take into consideration when determining where and what to build?	How well/often is public transport provision taken into account when buying land/planning a development?
		What do developers consider when determining the density of their development?
		What pre-conditions are required for developers to deliver higher densities (in appropriate locations)?

Theme	Lead question	Follow-up questions (and additional follow ups in blue)
		What do buyers/investors look for in medium/high-density housing? How have these trends changed or are changing? What do you think buyers/investors will be looking for in the future?
		How much importance to buyers/investors place on provision of car parks?
		How much importance do buyers/investors place on public transport provision?
		Do you have any examples of medium/high-density developments that have supported or enabled people to shift their travel behaviour to more sustainable modes? What were the factors that led to this success? Do you have any examples or evidence of this?
Iwi-led development	What conditions are needed to support/enable the delivery of papakāinga and other Māori housing developments?	What are the barriers to delivering papakāinga and other Māori housing developments?
		What would an ao Māori approach to a 20-minute neighbourhood look like? What conditions are needed to support/enable the delivery of this?

Appendix B: FranklyAI themes and questions

This appendix describes the themes and questions asked by the FranklyAI digital tool for this research.

B.1 Conversation themes

FranklyAI conducted a theme-focused conversation by asking leading premise-finder questions and follow-up premise question sets triggered by keywords in the premise-finder question responses. The premise-finder questions and premise question sets are grouped into three conversation themes: transport, neighbourhood and housing.

B.1.1 Transport

This theme aims to explore the how and why of people's travel.

Table B.1 Transport themes and questions

Leading premise-finder question: Tell me about how you usually travel in and around your town/city?	
Associated premise question sets	
Mode preferences	**Trip purposes**
• Why do you use the kinds of transport that you do? • Does using active transport options (like walking, cycling and scooting) work well for your current lifestyle? • Does using public transport work well for your current lifestyle? • What else, if anything, can you tell me about how you would like to travel around your town/city?	• What were your main reasons for travelling recently? • Have you had any barriers or difficulties while travelling around your town/city?

B.1.2 Neighbourhood

This theme aims to understand people's opinions on their neighbourhood and any related amenities.

Table B.2 Neighbourhood themes and questions

Leading premise-finder question: Tell me what you like about your neighbourhood?	
Associated premise question sets	
Neighbourhood preferences	**Neighbourhood amenities**
• Why kind of area do you currently live in? *(Multi-choice of inner city, outer city suburb, small town, rural, other)* • Do your existing transport options make it easy to connect with the people in your neighbourhood? *(Yes, No, It depends)* • How did transport options influence your current choice of neighbourhood? • Is there any place or kind of area you would prefer to live in? *(Multi-choice of yes or no)* • What place or kind of area would you prefer to live in and why? *(Only asked if previous answer is yes)*	• What kinds of amenities do you need nearby to live a good life? • Do you use these amenities frequently? And how do you usually travel to these amenities? • What would make active modes of transport (like walking, cycling and scooting) a more appealing way to travel for most of your needs? • And what would make public transport a more appealing way to travel for most of your needs?

B.1.3 Housing

This theme aims to understand people's opinions on their current housing situation and higher-density housing.

Table B.3 Housing themes and questions

Leading premise-finder question: Tell me about the kind of house you live in?	
Associated premise question sets	
Housing preferences	**Housing density**
• What is your current housing status? • What, if anything, do you like about the house that you currently live in? • And what, if anything, do you dislike about the house that you currently live in?	• What do you think about lower-density housing? • What do you think about medium and higher-density housing? • What types of transport do you think work best for medium and higher-density housing and why? • What factors, if any, would make medium or higher-density housing more appealing to you?

Appendix C: Qualitative research findings

This appendix discusses the key themes identified through the eight targeted stakeholder interviews and supplemented by the 135 FranklyAI conversation findings as they relate to:

- housing market, attitudes and preferences
- transport infrastructure, services, attitudes and preferences
- social infrastructure and local amenities
- legislation, regulations, funding and operation.

The findings in appendices C.2–C.7 are based solely on data obtained from stakeholder interviews (see section 3.2) and conversations conducted through FranklyAI (see section 3.3). Therefore, a range of different views are represented. The following sections do not incorporate any findings from the literature review.

C.1 Summary of interview findings

- Some people are more receptive to high-density housing. However, there continues to be a strong demand for stand-alone homes or the Kiwi quarter-acre dream. The housing market is demand-led. Therefore, New Zealand's predominant housing preferences limit the type of housing that is being brought to the market.
- The current high-density offering is not suitable for large, multi-generational families. There is also a negative perception about the quality of higher densities, which suggests there is a need for more examples of density done well.
- The cost of higher densities cannot always complete with stand-alone homes. For example, the cost of an apartment in the city is often comparable to the cost of a larger home in the suburbs. This reflects the land value gradient.
- Higher densities are higher risk and more expensive to develop, which affects the financial viability of this type of development. Land and infrastructure constraints also limit developers' ability to intensify sites and offer access to transport.
- There need to be genuine, affordable alternatives to private vehicles to enable mode shift. Currently, poor public transport coverage and performance limits uptake.
- Active transport will not always be feasible for everyone, regardless of urban integration. There is also a risk that certain groups' access will be further impeded if their ability to use cars is taken away from them or restricted.
- Sustainable transport options should be in place before development occupation to help embed positive travel behaviours.
- Smaller centres have a lot of potential for mode shift and compact urban form typologies. However, a different approach to reducing car usage is needed due to their unique opportunities and constraints.
- Density should be combined with a supportive built environment for optimal urban integration outcomes. Proximity to social infrastructure and amenities was cited as a key factor in people's housing decisions. Built environment aspects can also contribute to a strong sense of community, which can draw people towards higher-density neighbourhoods.
- Resource management tools (such as the NPS-UD and MDRS) have helped increase residential density and housing supply. However, there is a need for additional tools to support urban integration outcomes.
- The current funding framework for active mode transport infrastructure is fragmented, unagile, obscure and cost-inefficient and does not adequately value broader outcomes.

C.2 Housing market, attitudes and preferences

C.2.1 A rise in multi-unit dwellings but continued strong demand for stand-alone homes or the Kiwi quarter-acre dream

According to one of the interviewees, there has been a significant increase in terraced housing and walk-ups in Auckland and Wellington. In Auckland, this growth was initially attributed to the enabling provisions in the Auckland Unitary Plan. However, Wellington demonstrated similar findings without an enabling plan, suggesting growth was likely demand induced.

While there is an increasing supply of multi-unit dwellings in New Zealand, the number of single homes consented has remained constant and the number of apartments is not growing. Interviewees attributed the lack of apartments in New Zealand's cities to height limits, special character overlays and other regulatory constraints. Others contended that market demand for multi-storey apartments is not strong enough in some places. For example, several apartment buildings in Hamilton have been consented but are yet to commit to construction due to a lack of demand.

Meanwhile, there continues to be strong demand for large stand-alone homes and holiday houses or the Kiwi quarter-acre dream. Many FranklyAI respondents noted 'sunny' backyards and overall size as things they liked about their current home. A number specifically mentioned liking having a detached home, while comparably few discussed a preference for denser typologies explicitly. However, FranklyAI found that attitudes towards lower-density, detached homes were polarised – 'nice', 'luxurious' versus 'anachronistic', 'wasteful … ugly'.

C.2.2 Housing culture/preferences are a barrier to higher housing densities

Of those interviewed, most agreed housing culture/preferences in New Zealand are a barrier to uptake of higher housing densities. However, the most popular housing attributes cited among FranklyAI respondents were not typological but locational – being close to various amenities, having good views and receiving 'good light' were common responses. While not intrinsically tied to specific typologies, perceptions of higher-density living implies these attributes (particularly views and light) are usually associated with lower-density housing.

FranklyAI finding: A common view was that higher densities are necessary but that it 'wouldn't work for my lifestyle'.

While a large number of FranklyAI respondents shared the view that higher densities are necessary to provide the housing supply and choice that we need, this support came with caveats based on negative perceptions such as 'as long as they're built properly', 'good in areas with transport and amenities', 'convenient for a certain stage of life' and 'a good option for first-home buyers'. There were particularly strong perceptions that higher densities need to be built and designed better, with some sharing concerns that density 'done badly' could reduce social cohesion.

Lasting impressions of the leaky building crisis seemed to affect many FranklyAI respondents' perception of higher-density homes. These respondents were concerned that higher-density dwellings are not built well, and as a result, they are cautious about taking on what they perceive to be a 'risky' investment. In addition, some respondents felt that a history of poor build quality and materials in New Zealand has led to higher densities becoming associated with 'poverty'.

When asked what factors would make higher densities more appealing, quality design and build quality was the dominant response among FranklyAI respondents. This implies that resistance to dense development is largely due to a lack of faith that New Zealand has or enforces building and design standards.

C.2.3 Housing choices differ depending on commuting and housing experience

While there are negative perceptions of higher densities in New Zealand, one interviewee commented that the market is highly segmented, with some groups more receptive to higher density and others preferring stand-alone homes. Most agreed that housing preference differed depending on the city/town and people's commuting and housing experience.

One interviewee referenced the New Zealand Centre for Sustainable Cities Resilient Urban Futures Programme,[17] which found that Christchurch residents are more satisfied with a long commute because of the trade-off of a lifestyle block or large section and stand-alone home. However, a long commute in Wellington or Auckland does not necessarily mean having a large section and stand-alone home. People in Auckland and Wellington were also found to be more likely to want a smaller house with a shorter commute.

A developer confirmed that people immigrating or returning to New Zealand from overseas are more inclined towards apartment living. This was also evident in the FranklyAI findings – respondents with experience living in apartments overseas tended to agree that higher-density living is 'the future' for our larger cities. However, these respondents also stressed the importance of housing quality, design and proximity to quality public transport.

C.2.4 Housing and travel behaviour changed following COVID-19

The shift towards flexible work arrangements induced by the COVID-19 pandemic is now largely embedded, and people make use of this by considering broader options of living location – commuting further on some days and working from home on others. There is also an increased demand for space at home to work. As a result of these flexible working arrangements, employers are also looking to remove barriers for travelling into the office such as through providing end-of-trip facilities (showers, lockers, secure cycle parking).

C.2.5 Current higher-density offering not suitable for large, multi-generational families

The findings suggest that the range of medium-density and high-density housing typologies on the market may also be a barrier to uptake. In particular, most townhouses and apartments on the market are not suitable for large, multi-generational families, which is likely a reflection of current demand. For example, Kāinga Ora has homes and development sites in communities that are well serviced by public transport, social infrastructure and amenities, but some whānau are too large to live there or be accommodated in more compact housing typologies. One developer is considering alternative housing models that enable multiple generations and families to live together.

FranklyAI finding: Even respondents who expressed support for higher-density housing commented on low-density homes with backyards being 'great for families'.

To further demonstrate this gap in the market, an interviewee used the example of young families in Hamilton who want space and cannot afford a larger house in Hamilton so they are moving to Morrinsville or Te Awamutu to obtain the housing they want. This echoed several sentiments among interviewees and FranklyAI respondents that housing preferences and choices change depending on people's life stage. FranklyAI respondents nearly universally perceived medium-density and high-density homes as small, with many respondents remarking that detached homes with backyards were 'the best option for families'. Several respondents noted that having a dog made higher-density living unviable for them and their families.

[17] https://www.sustainablecities.org.nz/our-research/past-research/resilient-urban-futures-programme

One developer stated that they were only aware of a handful of children living in their developments. However, this may be a reflection of the developer's offering and price point, which typically attracts empty nesters or childless couples. Higher densities were seen by some FranklyAI respondents as a good option for first-home buyers who are usually perceived to be young couples without children.

C.2.6 New Zealand's new housing market is seen as demand-led but other market factors are at play

Several interviewees contended that the type of housing being built in New Zealand is demand-led and that developers cater to their target demographic and offering. For example, a high-end developer will typically prioritise views, proximity to water and walkability to amenities over public transport provisions as this is what their customers value most.

There was also similar discussion about a path dependency whereby people expect a large stand-alone home with a garage so developers aim to build this. One interviewee commented that developers build what they think investors will buy and investors buy what they think will get them a good return. As an example of this path dependency, a developer advised that buyers expect at least one car park in Auckland and sometimes two, so developers must supply them to sell apartments (although they generally do not make a profit from supplying them). In Wellington, the same developer advised that the provision of car parking is more flexible.

FranklyAI finding: Despite near universal agreement that public and active transport are the best transport match for higher densities, FranklyAI respondents commonly criticised medium-density developments for providing insufficient parking due to the perception that there is 'no alternative' to driving.

Another interviewee considered that we need vision-led development instead of catering for what the market wants, but this creates risks that investors and developers do not wish to take on.

A developer commented that they seek to make a substantial profit and require some confidence that people will purchase their products to achieve this. However, apartments are typically less certain than a new terraced house in suburbs further out of the CBD, which limits the type of development that is brought to the market. There is also no premium placed on apartments so banks are less willing to lend to developers.

C.2.7 Cost of higher densities cannot always compete with stand-alone homes or be financially viable

Some interviewees attributed the growth in multi-unit developments to the increasing cost of housing, and apartments were seen by some interviewees and FranklyAI respondents as an accessible first step into the housing market. However, the degree of support for higher densities as a more affordable housing option was comparable to the number of FranklyAI respondents who complained that higher densities are too expensive. In many locations, a high level of amenity (coupled with a smaller home) was not perceived by FranklyAI respondents to be 'worth' the price of a higher-density dwelling in an accessible area. This was echoed by a developer who commented that the price of an apartment in the city cannot compete with a larger home on a larger section further from the city. For example, it is hard to convince people to

FranklyAI finding: Respondents appreciated the greater housing choice provided by increasing numbers of multi-unit dwellings but stated the importance of its location – it must be central or near transport, social infrastructure and amenities. More affordable examples of medium density in suburban areas generally had poor perceptions.

spend $1 million on an apartment in the city when they can get a stand-alone home further from the city for the same price.

Many FranklyAI respondents expected medium density to be centrally located and close to public transport, social infrastructure and amenities. However, they also expected it to be more affordable than a stand-alone home. This can be difficult for developers to achieve as developments must stack up with the price of land and be financially viable. A developer commented that, in cities with large land value gradients (the further from the CBD, the cheaper the land), it is harder to get density in accessible areas as developers will opt to develop on cheaper land. The same interviewee thought market forces would eventually correct this but that it will result in many unintended consequences in the process (such as increased congestion and poor amenity outcomes). According to an interviewee, buildings three storeys or higher also requires elevators and additional fire infrastructure, which adds significant costs. These costs are further inflamed by increasing material costs and lack of skilled labour in New Zealand.

Public/community housing providers are subject to similar pressures as the private development industry. However, they also have the added pressure of short-term housing targets. An interviewee observed that it is a lot quicker and cheaper to build lower density, which often results in less public housing in good locations. While Kāinga Ora owns many properties in accessible areas (such as Mount Roskill and Northcote), it also owns a lot of properties in communities that are not well connected to public transport.

C.2.8 Land and infrastructure constraints limit the ability to intensify sites and offer access to transport

It was raised by interviewees that complex and/or split-ownership structures, particularly in desirable locations (such as around town centres) limit developers' ability to intensify sites in areas well connected to public transport. Hope is often placed on organisations like Kāinga Ora, which owns a large number of land parcels and has the legal power to amalgamate.

Greenfield development provides a unique opportunity to efficiently use land and create good design outcomes due to fewer existing constraints. However, it has a higher cost barrier for entry as developers need to provide lead infrastructure, which is typically a high capital spend. Fragmented ownership can also make this difficult. This reduces the number of development parties in New Zealand that can deliver in this space.

In saying this, one interviewee commented that not all land will be developed to 50 dwellings per hectare (terraced housing) if enabled (as an example of a potential policy). They went on to say that councils need to have a good understanding of their town/city's infrastructure capacity and consider it within a realistic future scenario.

FranklyAI responses also suggested a lack of confidence that adequate infrastructure will be supplied to support higher densities. In particular, multiple respondents were concerned that higher-density development coupled with poor public transport, walking and cycling options would lead to vehicle congestion and parking issues. Many respondents also said they felt like housing density was increasing without adequate additional green spaces.

Larger-scale developers have the ability to include amenities such as town centres and open space. However smaller-scale developers do not have that ability and rely on connecting to these amenities (town centres, parks and playgrounds).

The importance of 'good design' was repeatedly mentioned by FranklyAI respondents. However, designing to optimise privacy and daylight is likely to mean that developable capacity cannot be maximised.

C.2.9 More and better examples of quality dense housing and neighbourhoods are needed to 'sell' higher-density living

Several interviewees contended that the public do not recognise the benefits of higher-density housing in large part due to the lack of quality higher-density housing on the market so more and better examples of well-built, well-designed density that can enhance people's lifestyles are needed.

An interviewee used the example of how some products are marketed – customers do not know that they need the product until they are shown how it can complement and/or improve their lifestyle. This notion could be applied to marketing integrated, sustainable housing typologies and transport. Hobsonville Point in Auckland was mentioned by several interviewees as an example of successful medium-density development.

The top features cited by FranklyAI respondents when asked what they like about their current house were locational (being close to various amenities, having good views). Therefore, a key selling point for higher densities could be the (assumed) proximity to amenities. While many FranklyAI respondents demonstrated traditional Kiwi housing values and appear resistant to change where/how they live, a significant number of respondents were attracted to the proximity offered by higher densities. Some respondents also said that they would accept smaller living conditions if they had a clear outlook, were close to neighbourhood parks and communal areas and had a pleasant streetscape.

In addition, those FranklyAI respondents who live in higher densities cited the benefits of modern construction (warm, dry, energy efficient), proximity to shops and services (education, transport) and the sense of community/easy ability to socialise as features they liked about where they lived. This could also be a selling point of higher densities as many FranklyAI respondents complained about how cold and damp their existing dwellings were as well as the amount of maintenance their homes required.

C.2.10 Alternative housing models and papakāinga have potential to achieve broader outcomes than what is currently available on the market

Co-housing was identified in one interview as a way to create more affordable and better-quality housing. When urban integration is considered, there is potential for co-housing to achieve better health, wellbeing and equity outcomes than what is currently available on the market by providing affordable housing opportunities that are flexible to the needs and wants of occupants and communities. More work is needed to understand the barriers to delivering co-housing in New Zealand.

A developer also thought there could be a larger high-density market in some locations (than what already exists) for retirees as apartments are a good alternative to retirement villages in that they are accessible and easy to maintain.

While not the same as co-housing, interviewees reported a resurgent interest in the delivery of papakāinga, particularly in rural settings. Papakāinga is a term used to describe housing on ancestral Māori land and can include other activities associated with the nature and function of the papakāinga (Whangārei District Council, 2024) such as a marae, commercial activities or shared facilities (gardens, living spaces). An interviewee from local government shared the view that iwi would like to have ownership of the outcomes and development of papakāinga to provide housing for tangata whenua and would like a mix of urban and rural locations. However, location and available land area are a significant barrier in delivering papakāinga. This makes it much more difficult to deliver in an urban area.

C.3 Transport infrastructure, services, attitudes and preferences

C.3.1 Poor public transport coverage and performance limits sustainable transport uptake

Public transport coverage, frequency and reliability were fundamental issues cited by FranklyAI respondents that limit their propensity to use public transport. Many respondents said they do not use public transport because stops are too far from their home or their required destinations. Others for whom stops may be close enough still viewed public transport as impractical due to the limited frequency of services.

The FranklyAI respondents who said public transport works well for them generally lived on or in close proximity to a key public transport line or route. Respondents explained how poor reliability of public transport makes planning their days difficult and pushes them to drive or use alternative methods of transport.

Furthermore, during the COVID-19 pandemic, public transport had markedly lower usage than other modes due to concern about contracting COVID-19. Interviewees commented that the reduced traffic congestion following the pandemic may also have induced more people to drive as buses typically experience the same congestion and travel delays as cars.

C.3.2 Active and public transport not feasible for everyone regardless of integration

Several interviewees touched on the barriers to active and public transport for certain groups regardless of urban integration and access to these modes.

One interviewee commented that there are too many assumptions that people are able-bodied and will derive access benefits from living and working within proximity to public and active transport options. For example, moving someone to a ‘better location’ may in fact impede their access depending on their physical ability – walking 800 m to mass rapid transit versus 100 m to a bus shelter.

Distance was the most commonly cited barrier to active transport among FranklyAI respondents. However, safety, disability/injury and travelling with children were also commonly cited. Reliability, frequency and coverage were the key barriers to public transport use. Some respondents also reported feeling unsafe, while disabled respondents and those travelling with children noted they encountered difficulties in using public transport. People who faced barriers to using active transport modes were more likely to face barriers to using public transport modes.

One interviewee noted that public transport can be infeasible for large households/families – an outing for a family of six could cost $30 using public transport based on a $5 return fare – therefore access to a bus or train is unlikely to improve their access in the absence of more affordable fares. One interviewee shared results from the Kāinga Ora Transport Survey, which found that Kāinga Ora customers are more likely to use cheaper transport (walking, cycling, public transport) as opposed to a private vehicle or rideshare/taxi. The cost of public transport is also unlikely to be feasible for a primary household carer who needs to trip chain or make multiple stops for multiple purposes around the city/town in a day.

In one interview, an anecdotal suggestion was made that elderly people only travel when they know they can get a seat on public transport and avoid busy periods for this reason. Multiple FranklyAI respondents reported frustration at full buses in busy times and cited COVID-19 and the high number of cancellations as contributing to this problem. Some, including those with young children, also reported a desire for greater frequency of services outside the peak hours, calling for additional midday, evening and weekend services.

These examples highlight the need for equitable access and a more nuanced approach to urban integration that takes into consideration the broad and varying needs of the population.

C.3.3 Difficult to reduce people's ability to use cars without impeding accessibility and opportunities

There was also some discussion with interviewees about reducing people's ability to use cars (through demand-management tools such as reduced parking, congestion charging and fuel taxes) and how this would disproportionately impede access for certain groups that rely more heavily on private vehicles to access opportunities.

The interviews identified that there are some Kāinga Ora customers who find it difficult to access jobs by public transport. They therefore often rely on cars to get to work. When the household car breaks down, they may miss out on jobs or get fired because they cannot reliably get to their workplaces on time (by walking or taking public transport).

While some Kāinga Ora customers rely on cars, research from Kāinga Ora shows that customers do less driving (and therefore have a smaller transport emissions footprint) because they are more efficient with their trips (sharing rides and costs). This highlights the need to put Kāinga Ora residents' car use in perspective relative to the rest of the population.

C.3.4 Sustainable transport options should be in place before development occupation to help change travel behaviour

Interviewees mentioned opportunities for behaviour change that are often not leveraged. Specifically, they identified a lack of sustainable transport options being in place upon housing development completion as a barrier to behaviour change. In the examples of housing developments that were used, sustainable transport services were sometimes implemented months after development completion, by which time the normal transport mode for people living in the development had become car use. As a result, public transport uptake was low once the service had been implemented.

Interviewees reported mostly seeing a traditional approach to transport from the development community where there is little offered in the way of integrated transport or amenities. Some developers are considering offering bicycles, micro-mobility and car-share schemes in their developments. For larger developments, one developer is starting to think about the life of buildings and being able to convert car park buildings to commercial use by designing with increased ceiling heights and allow car parking to be removed over time.

C.3.5 Need for legitimate, affordable alternatives to private vehicles

Cost was cited by FranklyAI respondents who both used and did not use public transport as a reason behind their transport mode choice, reflecting the high cost of both car ownership (regardless of distance travelled) and public transport use. Some respondents commented that the public transport zoning system disadvantages those who cannot afford to live close to the city. For some, driving is cheaper. Some respondents also raised the cost of a bike as a barrier, highlighting inequalities in our transport system

An interviewee commented that it can be difficult to convince people to shift to public transport if they have invested in a vehicle and using public transport will not save them any money. Therefore, there need to be feasible non-private car options for most or all necessary trips to shift people out of cars. As many of the costs of car ownership apply irrespective of distance travelled, the cost advantages of public transport may only become apparent to someone if it is used frequently enough to enable them to sell their car.

In addition, the FranklyAI responses suggest the desire to live more 'car-lite' is more common than our national travel behaviour would suggest. A clear majority of people would prefer to walk to their nearest amenities, and while only a handful of respondents cycled regularly, nearly half said they wanted to cycle more. Safety and lack of quality walking and cycling infrastructure were repeatedly mentioned as barriers to mode shift, while better public and active transport was cited by many respondents as a key factor that would make higher densities more appealing.

C.3.6 Smaller centres have potential to achieve mode shift and more compact urban form typologies but different approaches needed to reduce car travel

There were several comments about smaller centres and their unique opportunities and challenges for delivering greater urban integration. One interviewee commented that the smaller scale of provincial/rural towns presents a large opportunity for urban integration and compact urban form typologies such as 20-minute cities (see section 4.2.5.2). For example, it would be possible to cycle across Rotorua in under 30 minutes. However, further work is needed to understand what compact, integrated urban form looks like at different scales in smaller centres as opposed to cities Similarly, another interviewee highlighted that e-bikes provide an opportunity for the 15-minute city, especially in smaller towns, but that this should be encouraged alongside the delivery of safe and accessible cycling infrastructure for these benefits to be realised.

While there are potentially large opportunities for compact, integrated urban form in smaller centres, they are also faced with unique challenges. A different approach is required to reduce car use over how it is done in larger cities such as Auckland and Wellington. Behaviour change is generally much slower in smaller towns, and residents in provincial/rural towns often have to travel large distances to work for place-based industries (tourism, hospitality, agriculture) and for their children to play sports (children play in regional sport leagues rather than local leagues) so a 'one size fits all' approach is not always appropriate. To help address this, one interviewee would like national and local government planning organisations to listen to local practitioners that understand the nuances of small centres' challenges or visit the place so they can see and experience the challenges for themselves.

State highways also play a more central role in the local transport system (compared to larger centres). One interviewee commented that they would like NZTA to remove constraints on reducing speed limits on state highways as speed currently limits their ability to achieve good safety and accessibility outcomes.

C.4 Social infrastructure and local amenities

C.4.1 Combine density with supportive built environment for optimal outcomes

Interviewees highlighted that proximity to work is a key factor in housing decisions. However, a common theme raised by interviewees is that density should also be integrated with accessibility to workplaces, social/community infrastructure and amenities as proximity to these is also valued. Density is important, but much broader outcomes and benefits are achieved when combined with a supportive built environment. Developers were receptive to providing dense housing around transport corridors and centres as this adds to their offering or value proposition.

Location and being close to amenities was a popular housing attribute among FranklyAI respondents. Most also indicated they preferred to walk to these amenities. Amenities commonly described as essential included parks and pleasant green spaces, tree-lined streets, a dairy or supermarket, shops, cafés, bars, a GP, a pharmacy and good public transport. Multiple FranklyAI respondents commented on the success of housing developments based on accessible social infrastructure and other amenities (such as Hobsonville Point).

C.4.2 Sense of community can draw people to higher-density neighbourhoods

It became clear throughout the interviews that people (especially families) highly value a sense of community. This was also mentioned by FranklyAI respondents, with many reporting that higher densities helped to create a stronger 'sense of community'. Therefore, while it is important to ensure people can easily access workplaces, social/community infrastructure and amenities, there is also a need to create communities that support social interactions and connections. This has the potential to draw people towards higher-density housing and may be especially influential in the housing decisions of families.

C.5 Legislation and regulatory barriers

When interviewees were asked questions regarding barriers to higher-density integrated developments, many expressed that there were specific difficulties faced due to the regulatory planning framework.

C.5.1 Current system does not enable long-term planning (30+ years)

Several interviewees mentioned that New Zealand's focus on planning was at the resource consent level instead of strategic long-term planning. This makes achieving integrated urban outcomes more difficult. In New Zealand, territorial authorities review their district plans (which include the district's objectives, policies and rules) every 10 years. Often, territorial authorities do not have the resources to plan further ahead for each area within a district. There is also perceived to be a high level of uncertainty in the future planning space. This makes it difficult for agencies to know how to prepare for future changes, including changes to local government, RMA and three waters legislation. One interviewee commented that there needs to be one clear policy voice from central government providing direction on planning matters.

One national planning organisation commented that it can influence urban form through formal district plan processes such as submissions and appeals. However, due to the prevalence of private plan changes, urban form can be beholden to the market especially if the region subject to the plan change does not have a non-statutory document such as a spatial plan or structure plan to guide development.

C.5.2 Councils working in different legislative and regulatory frameworks creates tensions

Councils are generally trying to achieve the same things, but there are tensions between their unique legislative and regulatory frameworks. Some respondents felt that councils are 'at the mercy' of developers due to the power of the market in the development sector, exemplified through the prevalence of private plan changes. Conversely, other respondents considered that councils' planning provisions were too restrictive. For example, one interviewee was concerned that district plan overlays, particularly special character overlays, restrict intensified forms of development. Interestingly, while a handful of FranklyAI respondents noted that character elements were a key feature they liked about their own house, character/heritage was rarely mentioned as a valued feature at a neighbourhood level. Another interviewee specifically raised public transport as an area they considered fragmented, with misalignment between delivery and funding preventing an efficient, frequent and inclusive service.

C.5.3 Resource management tools have increased residential density and housing supply but a need for additional tools to support urban integration outcomes

Several interviewees commented that the NPS-UD, MDRS and special housing areas have been helpful for councils to enable higher densities and boost housing supply, particularly in areas where there is strong public and/or political resistance to density. Others, however, criticised that the approach does not address

infrastructure issues and costs and does not necessarily balance yield with good design outcomes. The MDRS were also specifically criticised for enabling density where it should not go, with interviewees commenting that they lacked policies around amenity and mixed-use developments and were likely to result in a 'growing pain' period where growth, accessibility and amenity find a balance.

There was optimism that the RMA reforms will help to achieve urban integration outcomes. Many interviewees stressed the importance of coordination and partnership between different agencies and different levels of government such as through spatial planning and urban growth partnerships, stating that these were good tools for long-term planning. One interviewee mentioned the need for further/additional regulatory tools for managing urban form, particularly in the realm of traffic demand management.

C.6 Funding

C.6.1 Public transport funding and delivery fragmented and reactive, not proactive

A common theme in the interviews was the perceived lack of integration between planning, funding and delivery of public transport. There is a need for more collaboration between transport providers and developers as the currently 'underfunded and privatised' system makes it expensive to provide effective public transport. Interviewees suggested shifting the focus of the funding model for public transport from cost-recovery towards providing an essential service, noting that there is simply insufficient funding (both capex and opex) currently available to achieve these aspirations.

Interviewees also expressed frustration that public transport delivery is reactive to development. The current approach means underinvestment results in a service that does not meet requirements, and car-centric solutions are then implemented as a fallback. Interviewees thought public transport providers instead need to coordinate with developers when considering future development, pre-empting demand and establishing high-quality, high-frequency services in the first instance.

C.6.2 Active transport infrastructure funding non-agile, obscure, cost-inefficient

Interviewees provided suggestions as to how funding could be better allocated. These include separating walking and cycling from the National Land Transport Fund and creating a fund for local authorities that transparently finances these projects on a more agile basis. The current practice of bundling cycleways with other projects (such as drainage and streetscape improvements) means there is little clarity over the true cost of cycleways, and it was noted that the public perception of the cost of cycleways is a contentious issue. It was also suggested that Kāinga Ora should be able to access funding to be more effective at urban integration and to tie this funding to active mode outcomes. There were no FranklyAI responses that commented on the cost of cycleways or wanted fewer of them.

Additionally, there were suggestions that the asset renewal process could provide opportunities to be more cost-efficient in delivering active mode infrastructure where level of service improvements for cycling, walking and public transport should be included in this programme as standard.

Support for improved walking and cycling infrastructure was high among FranklyAI respondents, with approximately 50% of respondents indicating they would like to cycle more. Many respondents expressed frustration that a lack of safe cycling routes prevents this.

C.6.3 Business case framework does not adequately value social outcomes

Several interviewees discussed how the requirement for investments to have commercial outcomes did not adequately recognise or value social outcomes. This results in 'broken' investment frameworks that are

primarily residential and do not provide the amenities required. They commented that small projects are rarely going to meet commercial thresholds and that wellbeing outcomes should be included in order to help investments 'stack up'.

Interviewees shared frustrations that the business case process is long and insufficiently agile, meaning it does not account for change happening during its development. This puts them out of date and adds recalibration costs and delays. The large financial and economic expense of business cases makes them a large sacrifice if the project does not go ahead while also restricting the amount of funding available to implement the project at the end. Nevertheless, the business case model has been described as still the most effective decision-making process. Further suggested improvements are to include various sustainability metrics as primary KPIs and to allow the recognition of long-term social benefits within them.

C.7 Operational barriers

C.7.1 Shared outcomes not being carried through the process

There was some discussion about there being broad support for urban integration opportunities. However, shared outcomes are not being carried through the project life cycle and seem to dissolve over time.

One interviewee commented that asset owners do not always agree with what the outcomes should be, and decisions are made on the basis of asset management and traffic modelling instead of the community outcomes sought. For example, one interviewee sought to bring about pedestrian improvements and increase play opportunities but the final decision only resulted in a wider footpath. There were similar discussions about being well aligned with project partners. However, it was noted that challenges often emerge at the operational level. One interviewee called for operational and strategic arms to be aligned and work better together.

It was noted that some national and local government organisations are not the final decision makers – they can only influence or partner with decision makers. They can, however, ensure that their teams have sufficient capabilities, capacity and the correct skills to apply what they can in decisions they do control.

C.7.2 Research is not yet influencing the delivery of urban development

There was an important observation made that research is not yet influencing the delivery or decision making about residential developments in New Zealand. One interviewee recommended getting research findings in front of the right people (such as investment teams). Similarly, one interviewee commented that the traditional vehicle level of service model[18] is used extensively but not used well or accurately, resulting in poor sustainability outcomes. They recommended road controlling authorities improve use of this or that a new and improved framework is developed that is fit for purpose for measuring sustainability outcomes.

C.7.3 Difficult to convince people to make trade-offs in favour of more sustainable urban form and transport

A common theme raised by interviewees was that perception and behavioural change in relation to housing and transport is necessary. However, this is difficult to influence due to New Zealanders' historical housing and transport preferences.

[18] The quality measure of how well road conditions provide for road users (Waka Kotahi, 2024a).

It was noted that, in New Zealand, the public generally views lower-density living as attractive and car ownership as necessary and that higher-density housing goes against the ‘quarter-acre dream’. This is largely a result of Kiwis historically being provided with few housing and travel choices and with little compromise for less-sustainable choices (low-density housing and car travel). Therefore, it is difficult to convince people to make trade-offs in favour of more sustainable urban form and transport. This is not necessarily just a ‘carrot and stick’ situation. There is a ‘historical carrot’ that must be removed.

C.8 Conclusion

It became clear through the interviews with stakeholders that there is no one ‘silver bullet’ and that a combination of many elements and measures is needed to enable effective urban integration in New Zealand. There is also a need to think beyond just density and transport and improve the built environment more broadly.

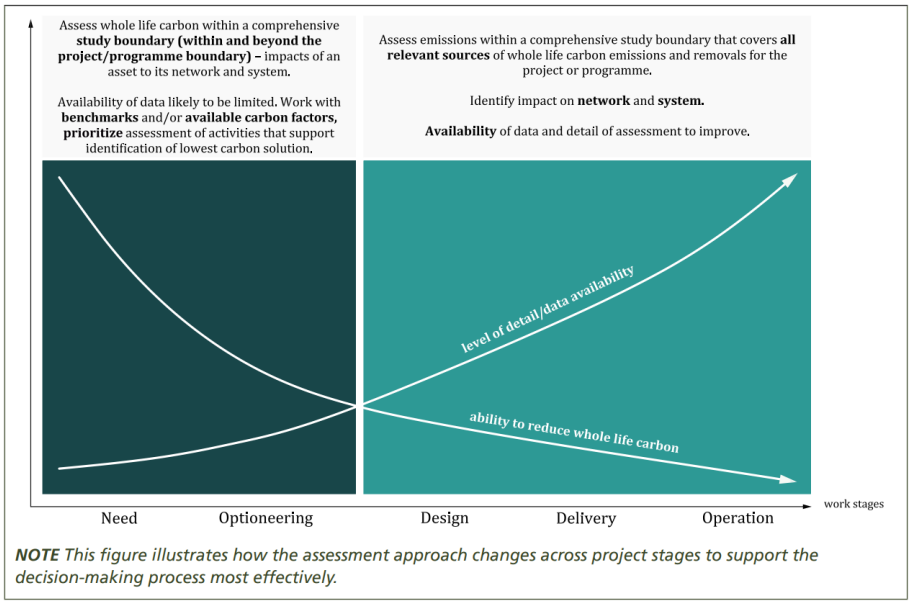
Appendix D: Methodology and guidelines for the expansion of the sketch planning tool

D.1 Introduction

As part of this research paper assessing sustainability of urban form and transport relationship, Beca Ltd was commissioned to develop a methodology and concept design for a tool that estimates the transport impacts from spatial plans of different urban forms. The tool is capable of assessing different social, economic and environmental measures, the focus of this research being carbon emissions related to the transport sector.

In the past, strategic transport models have played a crucial role in evaluating transport impacts of urban developments. Typically, spatial plans for future developments are converted into land-use assumptions, which can then be modelled as different scenarios to assess their influence on transport in detail. However, while these models are built with a wealth of technical research behind them, there are a few obstacles that prevent these models from being widely adopted throughout the planning process. First, many of these models are vehicle centric and do not consider active modes. Second, these models generally require detailed input data to run, which often is not available at the initial planning stage. Third, due to the complexity of these models, scenarios are usually time consuming to set up, run and interpret. The graph from PAS 2080:2023 *Carbon management in buildings and infrastructure* (Figure D.1) illustrates the dilemma of not having enough detailed data to support sensible prioritisation of projects early on, which is when the ability to reduce whole-life carbon is highest.

Figure D.1 Degree of accuracy and data availability in whole of life carbon assessments across work stages (reprinted from PAS 2080:2023, p. 25)



Source: https://www.bsigroup.com/globalassets/localfiles/en-th/pas-2080/pas2080_final-th.pdf

Through internal research and a subsequent project in Rotorua, Beca has developed and applied a multi-modal sketch planning tool. It can be used to estimate high-level travel demands and the associated emissions by mode in response to different land-use and network assumptions.

Developed following the same principles of traditional four-stage transport models, the sketch planning tool has a solid technical base but is still generic enough to generate outputs quickly from simple set-up. The concept of this sketch planning tool forms the basis of the methodology for this project. Furthermore, this project explores incorporating NZTA's recently completed carbon footprint research that assesses the embedded emissions from transport infrastructures (Tapper et al., 2024).

With permission from Rotorua Lakes Council (RLC), we applied the concept design for the expansion on the sketch planning tool previously developed to assess land-use scenarios for Rotorua Lakes Council Future Development Strategy (RLC FDS).

This document covers:

- the background information on the existing tool and resources that formed the basis of this research in section D.2
- the initial methodology proposed in section D.3
- the input data specification for the research (using RLC FDS as a case study) in section D.4
- the process to incorporate the carbon footprint research into the sketch planning tool in section D.5
- the recommendation for implementing tools to assess transport emissions in the future in section D.6.

D.2 Background research

D.2.1 Sketch planning tool

The sketch planning tool can estimate high-level transport outcomes by mode based on network and land-use inputs. It is a simplified four-stage transport model built within Excel. It is also multi-modal taking account of car, public transport, walking, cycling and trucks.

With the simplified structure, the tool is easy to set up and quick to run while still providing a sensible high-level response to land-use and network changes with relatively simple tuning. However, although it follows the same structure of a traditional transport model, it is much more simplified and not developed to the same level of complexity.

This simplification has efficiency and benefits but has inherent limitations relative to more detailed transport models. The tool is therefore best suited for comparative analysis between scenarios to narrow down the preferred option, especially where only high-level planning information is available.

To inform the FDS process, Beca was commissioned by RLC to adapt the sketch planning tool to the local context. The calibrated tool was used to assess potential transport outcomes between various land-use and transport scenarios and provide insight into the preferred strategy.

Figure D.2 depicts the model structure from this implementation, and details on the functionality for each stage and the corresponding specifications for the sketch planning tool implementation are shown in Table D.1.

Figure D.2 Sketch planning tool model structure: model parameters, stages and outcomes

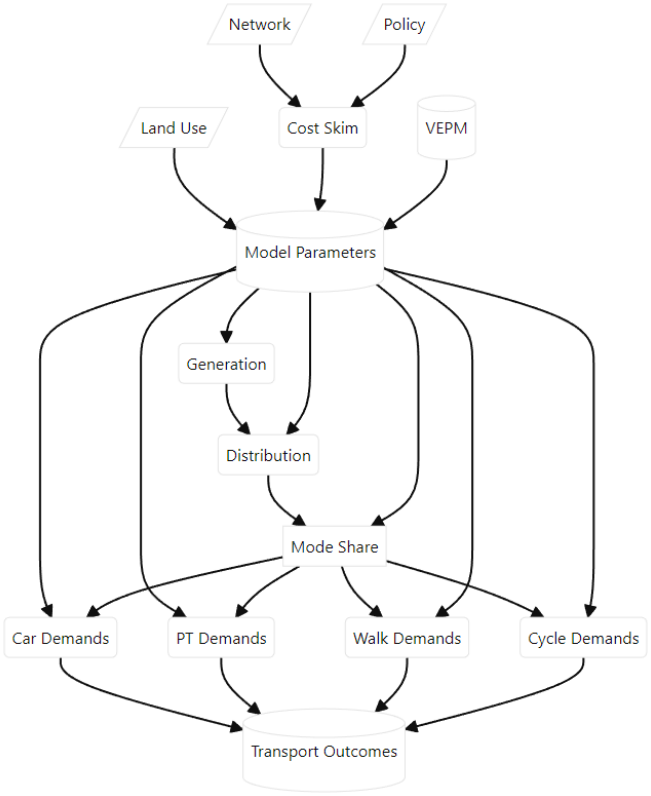


Table D.1 Sketch planning tool model stages

Model stage	Description	Model scope
Cost skim	Calculate the shortest path between origin and destination traffic analysis zones (TAZs).	Shortest path generated from the travel time on network links. Travel time derived from adjusted speed on link segment (from posted speed information) without link capacity constraints.
Generation	Calculate total daily person trips produced by population and attracted to the activities (such as employment) within individual TAZ by trip purposes.	Trip purposes: • Home-based work • Home-based education • Home-based other • Non-home-based business • Non-home-based other • Trucks
Distribution	Gravity model distribution of production trips within an individual TAZ and TAZs to attraction TAZs based on their relative accessibility.	Generalised cost components (for accessibility): • Travel time by mode (based on shortest path distance and travel speed between the zonal pair) • Vehicle operating cost (fuel and fleet composition) • Parking and toll cost • Public transport fare
Mode share	Distribute trips by trip purposes across different modes. Multi-modal logic choice model by purpose.	Modes: • Car • Public transport • Walking • Cycling
Assignment	Link (road) level assignment was not undertaken.	

Model stage	Description	Model scope
Outcomes	A range of transport-related outcomes can be produced. These are available by mode.	• Total trips by mode and mode share • VKT by mode • Total hours of travel by mode • Total revenue (including fare, parking, tolls)

The tool was calibrated to reflect 2018 conditions for the base year scenario for which census data, traffic counts on key corridors, survey information and VKT data in the study area were utilised.

The assessment of scenarios was carried out in two phases for RLC FDS – phase 1 focused on testing of different spatial plans (land-use changes), and phase 2 focused on transport system sensitivity tests (network changes).

D.2.2 Carbon footprint research project

NZTA's carbon footprint research project was developed to quantify the embodied emissions associated with land transport infrastructure. Assumptions around the construction under typical design standards (material type, material quantity, construction methods, maintenance, operation and end of life) were used to derive a set of profiles by asset type within the national road assessment and maintenance management (RAMM) database.

Profiles represent a standardised infrastructure asset and were developed using a combination of research, technical knowledge from environmental and sustainability subject matter experts as well as asset management teams and using the Project Emissions Estimation Tool (PEET) (Waka Kotahi NZ Transport Agency, 2023a). The research assigns each profile with an emissions factor based on these assumptions. Assets from the RAMM database are aggregated into profiles with other assets with a similar material composition. The carbon research analyses the whole-of-life emissions, including material and construction, maintenance, operation and end of life.

D.3 Initial methodology

Building on the existing sketch planning tool, which estimates changes in travel demand and transport emissions (enabled emissions)[19] in response to spatial planning inputs, we propose the following method to integrate the carbon footprint research into the tool. This will enable changes in transport-related horizontal infrastructure[20] (RAMM assets) and their associated emissions (embodied emissions)[21] to be quantified in response to the urban form of different spatial planning inputs.

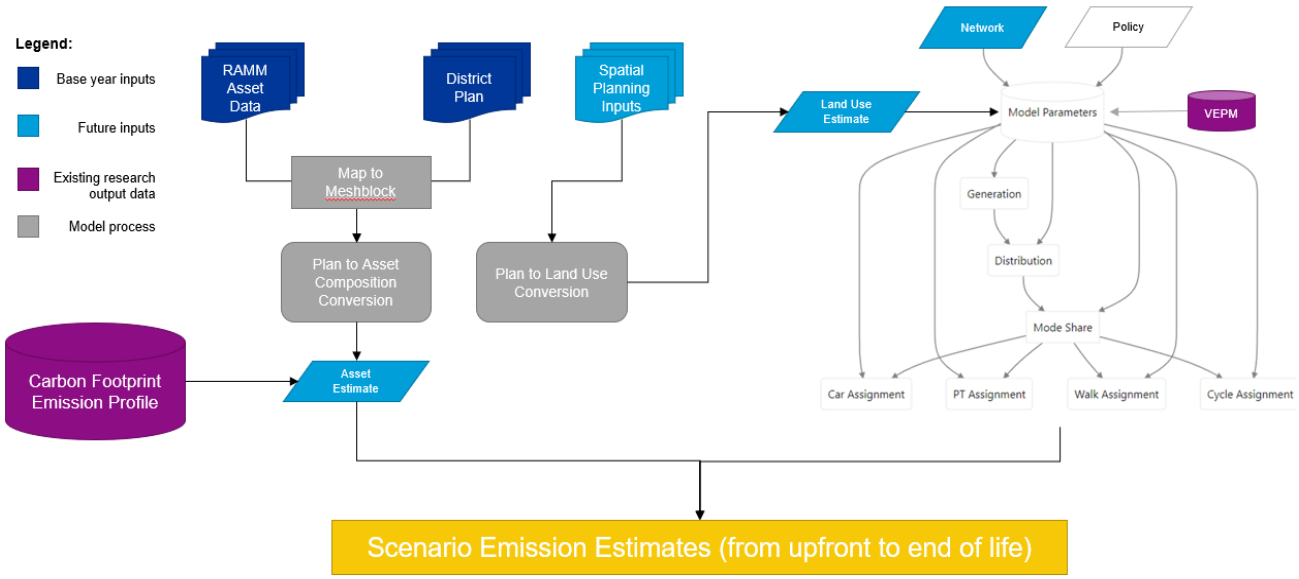
The process of obtaining this is summarised in Figure D.3.

[19] Refers to emissions from the vehicles using the land transport system – the output from the sketch planning tool is the net outcome from both induced and avoided emissions.

[20] Infrastructure required to support the movement of goods and people, particularly infrastructure that is longer than it is wide (roading rather than buildings).

[21] Also known as embedded emissions, this refers to the GHG emissions generated during the production and transportation of goods from the extraction of raw materials to the manufacturing process and final delivery to the consumer.

Figure D.3 Initial methodology for the expansion of the sketch planning tool to include embedded emissions



As part of the RLC FDS, the land-use conversion that takes spatial plan inputs into land-use estimates has already been completed. The focus of this research is therefore on the expansion of the tool to include enabled emissions using the available RAMM dataset for RLC and the carbon footprint research.

The next section provides details on the data used for both the tool expansion and the original development of the sketch planning tool.

D.4 Data sources and specifications

This section provides specifications for the input data used in the tool development. This includes:

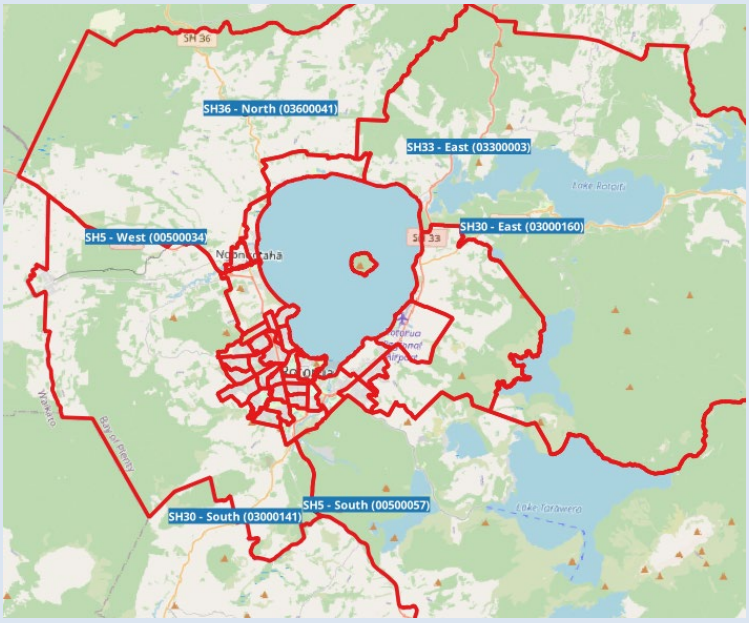
- for quantifying enabled emissions:
  - sketch planning tool developed for the RLC FDS project covering base model assumptions (land use, network and calibration) and future scenario spatial plans
- for quantifying embodied emissions:
  - RAMM asset database from RLC for determining the make-up of horizontal infrastructure (assets) within the existing study area
  - zoning information from RLC that defines existing zoning plans in the study area
  - emissions profile by RAMM asset type from the carbon footprint research.

D.4.1 Sketch planning tool

D.4.1.1 Base land-use assumptions

Land-use information for the study area is modelled by TAZs based on statistical area 2 (SA2) units defined by Stats NZ – 39 SA2 TAZs are included in the study area for this project, and six external TAZs are also modelled in the tool at the state highway entry points (Figure C.4).

Figure D.4 RLC study area and TAZ descriptions

Study area	Descriptions
	**39 internal TAZs** TAZs (outlined in red) based on 2018 SA2 boundaries in RLC, excluding the regions that are outside the focus area: • Golden Springs • Ngakuru • Arahiwi **6 external TAZs** Point locations (blue) based on state highway entering and exiting the study area, including: • SH26 North • SH5 West • SH30 South • SH5 South • SH30 East • SH33 East

Census 2018 information for SA2s was used to create the base year land-use information for each internal TAZ, which includes the following categories:

- Population and households.
- Employment by industry type (agriculture, education, industry, retail and services).
- School by type (primary, secondary and tertiary school roll from Ministry of Education).

Traffic counts from NZTA TMS (traffic monitoring for New Zealand state highways) are used to derive the production and attraction trips for external TAZs.

D.4.1.2 Base network assumptions

The One Network Road Classification (ONRC) network from NZTA was used as the basis for the base year network input, with minor edits[22] to ensure connectivity. Speed limit information from NZTA for the region is overlaid on the network and adjusted based on road classification to simulate operating speed. A shortest path algorithm is run between all origin and destination TAZ pairs on the network to derive distance, travel time and average speed, including for:

- car (with adjusted speed from posted speed information)
- walk (with 5 km/h travelling speed)
- cycle (with 15 km/h travelling speed)
- public transport (where public transport service is available, same speed as car with minimum service headway added travel time; walking speed is assumed for access time or where public transport service is absent).

The information between each origin and destination TAZ across all modes is then converted into generalised cost (in minutes) using the assumptions in Table D.2.

[22] The ONRC GIS network from NZTA contains road centreline information representing roads of all categories within New Zealand. Edits were made to detect unconnected road centreline segments (links) and create and snap bounding nodes.

Table D.2 Assumptions for the conversion of travel time information to generalised costs

Parameter	Specification	
Value of time ($/hr)[23]	Home-based work: $29.67 Home-based education: $16.55 Home-based other: $16.55	Non-home-based business: $69.70 Non-home based other: $16.55 Trucks: $49.46
Fuel consumption (L/100 km) and perceived price ($/L)	Consumption from the VEPM, using average speed between each origin and destination TAZ pair. Price based on $2.19 per litre for light and $1.41 for heavy (based on historical fuel data from figure.nz). The overall fuel cost is reduced by a 50% perception factor for light and 25% for heavy.[24]	
Public transport fare ($)	$2.80 flat rate for public transport generalised cost for all TAZ pairs	
Perceived parking cost ($)	City centre (adjusted with assumed participation rate): • Home-based work: $3.00 • Home-based education: $1.80 • Other purposes: $1.00	Airport (adjusted with assumed participation rate): • Work trips: $5.72 • Education trips: $3.43
Alternative specific constant) for non-car modes (mins)[25]	All non-education trips: • Public transport: 0 mins • Walk: 5 mins • Cycle: 36 mins	Education trips: • Public transport: 20 mins • Walk: 0 mins • Cycle: 20 mins

D.4.1.3 Base model calibration

While the sketch planning tool is a simplified version of a traditional four-stage model, its base model calibration procedure tries to align with the transport model development guidelines from NZTA, where applicable.

The base year model was calibrated using observed data from:

- 2018 census journey to work and journey to education data
- Rotorua city centre survey
- National Vehicle Emission Dataset (NVED) for 2018.

Using this information, relevant model parameters are tuned so that the model response for the following components is reflective of the observed data at a high level:

- Traffic generation for home-based work and home-based education trips.
- Mode share for home-based work and home-based education trips.
- Average trip length for home-based work and home-based education trips.
- VKT within the study area.
- Traffic volume on key corridors.

D.4.1.4 Spatial planning inputs

Dwelling yield and industrial business land area information was provided for individual development areas for the following four scenarios:

- Ngongotahā growth.

[23] Based on other strategic model assumptions (Tauranga and Auckland) and further refined during calibration.

[24] On the basis that motorists don't account for full costs of travel when making decisions.

[25] Calibrated to match overall mode share.

- Multi-nodal intensification.
- SH36 growth corridor.
- Eastside growth corridor.

This data was provided by RLC as a geodatabase consisting of 72 areas that represent the vacant land suitable for future residential and industrial development. These development areas were mapped to TAZs and converted to the model land use depending on the planned future land-use type. Depending on the scenario, there are up to 10 land-use types in the spatial plan:

- Mixed Commercial
- Rural Residential
- Residential
- Medium Density
- Heavy Industrial
- City Centre
- Commercial
- High Density
- Light Industrial
- Mixed Use

D.4.2 RAMM database

The RLC RAMM database contains information on infrastructure and assets within Rotorua, including the geospatial properties, size, material construction and other identifying attributes. The scope of this research covers transport-related horizontal infrastructure, which for RLC includes 18 different asset types:

- Footpath
- Traffic Signal Control
- Drainage
- Railing
- Sign
- Street Light Pole
- Traffic Island
- Pavement Structure
- Marking
- Bridge
- Retaining Wall
- Bus Shelters
- Surface Water Channel
- Berm
- Surface Structure
- Minor Structure
- Carriageway Section
- Treatment Length

The geodatabase for each of these assets has been made available for this research. These were taken as of May 2023. Data availability and granularity varies across and within asset types. Assets had different geospatial geometries that will need to be considered during the analysis:

- Point
- Polygon
- Linestring
- Multi-polygon
- Multi-linestring

D.4.3 District plan (city zoning plan)

RLC has provided zoning information in a geodatabase that contains information on the current land use in Rotorua. The zoning plan separates the region into 1,838 geographic areas (referred to as land-use area), varying in size from 0.006 m² to 3,468,510,556 m². The data includes the unique geospatial properties and land-use type for each geographic area. There are 32 different zone types in the dataset, which group neighbouring geographic areas into clusters. Of these, there are 13 zoning plan categories:

- Water
- Reserve
- Rural
- Residential
- Commercial
- Industrial
- City Centre
- Business and Innovation
- Lakes
- Future Reserve
- Future Residential
- Future Rural
- Transitional

D.4.4 Emissions profiles

The carbon footprint research uses national RAMM data to assign assets of different compositions to the closest profile. Profiles represent a typical infrastructure asset, each with a unique set of emissions factors (including construction, end of life and maintenance). The carbon research summarises emissions profiles for the following 13 asset types:

- Footpaths and cycleways
- Traffic lights
- Drainage
- Railings and barriers
- Street signs
- Street lights
- Traffic islands
- Pavements
- Road markings
- Bridges
- Retaining walls
- Public transport stations
- Surface water channel

D.5 Methodology refinement

Combining the carbon footprint research into the existing sketch planning tool requires two parts – determining a process to find the asset composition (the density of different asset types within an area) of spatial plans and mapping assets to the corresponding emissions profile in the carbon footprint research. This is achieved by finding the current asset composition of different land-use types by building relationships between the available RAMM data and RLC city zoning plan. The RAMM data is then mapped to the carbon footprint research to quantify the associated embodied emissions. The carbon footprint research quantifies upfront, maintenance, operational and end-of-life emissions. Once a relationship is established, these can be applied to the future spatial plans based on the expected land use. The tool can then be used to compare each of the four scenarios in the future development spatial plan. The following sections document the exploration process that ultimately led to the refinement of the initial methodology.

D.5.1 Preliminary analysis

This section summaries the key findings of the preliminary analysis, which provides a basic understanding of the available data and highlights potential limitations before determining the capabilities and scope for a more detailed analysis.

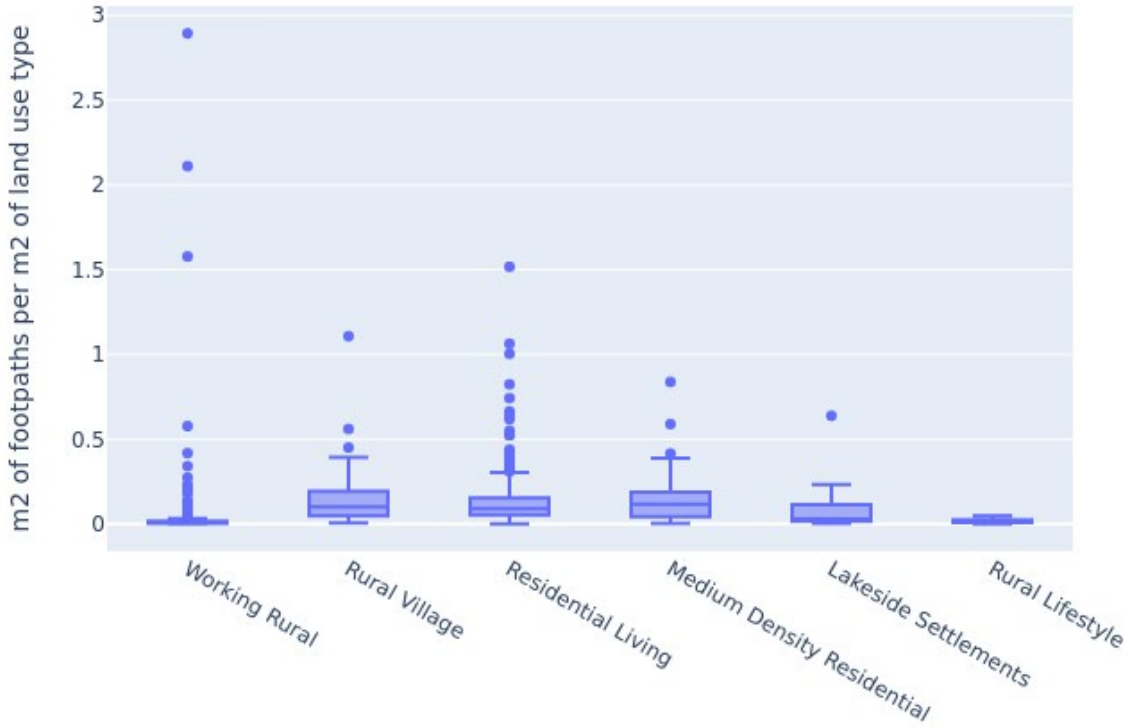
To begin with, the key datasets were visualised geospatially to provide an initial understanding of the relationship between the existing horizontal infrastructure and land use in Rotorua. To achieve this, the current RLC city zoning plan geodatabase was plotted over the top of the geospatial location of the RLC RAMM assets to assess how many assets fall within the boundaries of each zone. This highlighted one of the first key limitations in the data. The land-use areas defined in the RLC district plan do not cover the entire study area. The road space itself was not included within most of the land-use areas. As the majority of transport-related RAMM assets fall close or within the road carriageway space, most did not fall within a zone boundary. This issue is discussed further in section D.5.2.

To continue with the preliminary analysis, rather than assessing the number of assets that fall within a zone (joining where zone overlaps asset), assets were instead joined to the nearest zone within 50 metres. As discussed in section D.4.2, each asset in the RAMM dataset had a different geospatial geometry. Depending on the geometry as well as the asset type, the dataset contained either a width, length, area or count unit measure. To determine the relationship between assets and land-use areas, the unit measure for each asset type was summed for each land-use area. A unit per area factor was determined for all assets and land-use areas by dividing the zone area by the total sum of the asset type within 50 m of the land-use area. To understand the relationship between assets and land use, land-use areas were grouped into their zoning

types. The asset per unit factors for each zoning and asset type were plotted to see whether these factors were reasonable and could indicate any relationships.

Figure D.5 shows the area of pavement per square metre area of land within rural and residential land-use areas. While much of the data seems reasonable, there were a considerable number of outliers with some land-use areas having a greater pavement area than the zone area itself. Joining pavements to the closest zone within 50 m appears to overinflate the quantity of pavements that fall within each zone. The asset to land use relationship building process must be refined so that assets are more accurately mapped to zones.

Figure D.5 Area of footpaths (m²) per zone area (m²) by land-use type



D.5.2 Implementation

This section provides more details on the implementation issues highlighted in the preliminary analysis and documents the solutions taken to resolve them. At a high level, the issues can be summarised into four categories:

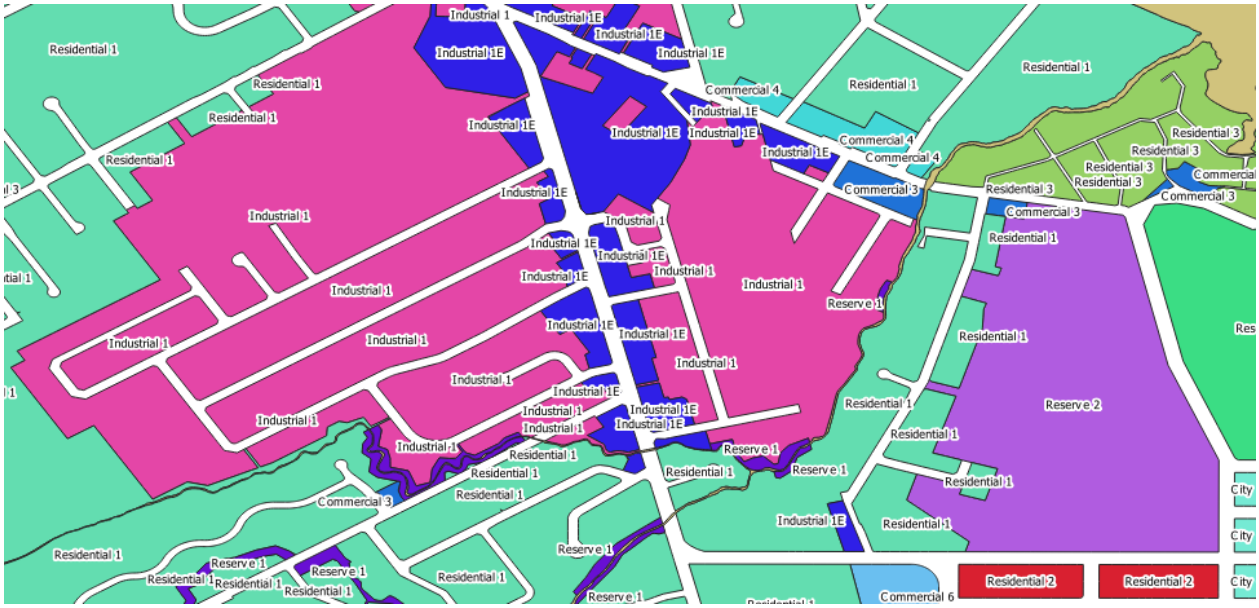
- The RLC zoning plan does not cover the entire study area (the road carriageway space is not included).
- City plan zoning information may not match with spatial plan zoning definition.
- Some asset type profiles were derived from other assets (extrapolation required from other data sources).
- Deriving statistically significant relationships between asset composition and zoning types.

D.5.3 Issues

D.5.3.1 The RLC zoning plan does not cover the entire study area (the road carriageway space is not included)

Figure D.6 shows the RLC zoning plan mapped geospatially. Colour indicates the coverage of different zone types, and white shows areas not covered in the city plan zoning data. This shows that most of the road carriageway space (showing in white on the map) is not covered in the city plan zoning data.

Figure D.6 RLC zoning plan example area



In Figure D.7, pavement RAMM data has been plotted along with the RLC zoning plan. The map depicts an example with the pavement assets (in pale pink) in relation to the city plan zoning boundaries. This indicates how most (if not all) horizontal infrastructure assets for our study area would fall within the road carriageway space. In addition, Figure D.7 shows how a single pavement segment can pass through multiple zoning types (as highlighted by the black square). Mapping assets to zones using conventional spatial joining methods with the current data would therefore be challenging and inaccurate. The refined methodology must consider how to map and proportion these assets into a zone.

Figure D.7 RLC zoning plan and pavement RAMM data example area

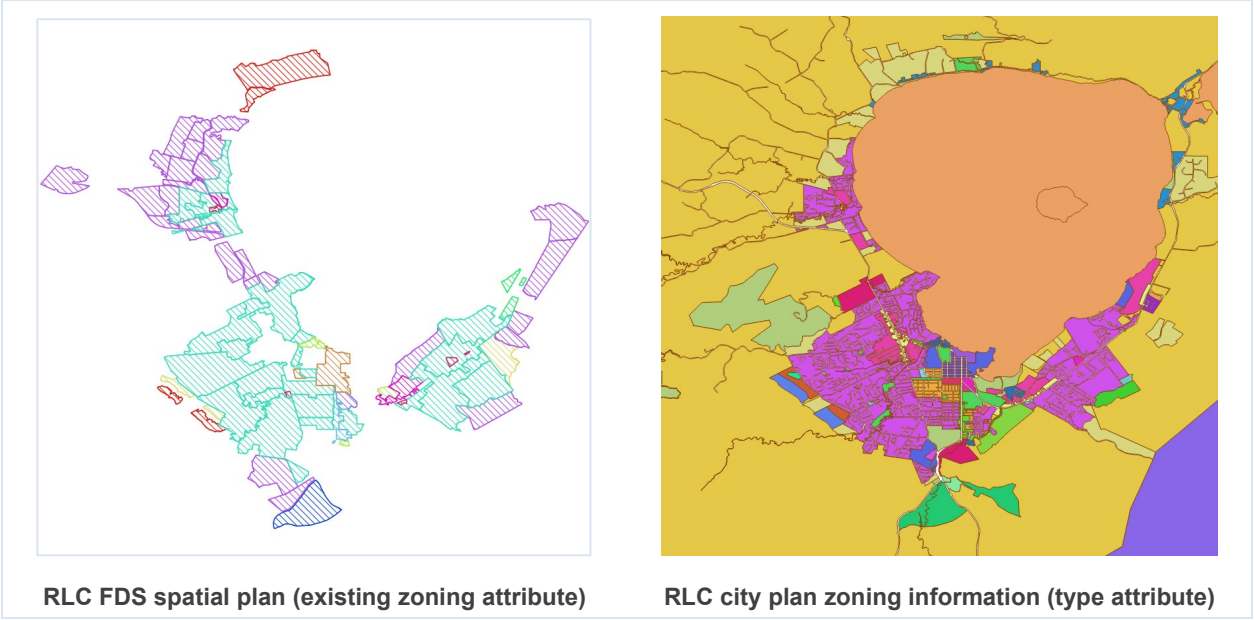
Splitting the asset segments to adhere to the zoning boundaries so that a one-to-one correspondence relationship can be established would be a complex and labour-intensive exercise. Moreover, given the coarseness of the input data and the likely variability in the potential outcome, the added complexity may not see material changes in the final accuracy of the modelling results.

A more effective method is to map both asset and zoning information to a common standardised spatial area as an interim step. For this research, meshblock boundaries are a good candidate as the database has full coverage of the region but also a many-to-one relationship with the spatial boundaries used in the sketch planning tool (multiple meshblocks make up one SA2).

D.5.3.2 City plan zoning information may not match with spatial plan zoning definition

As mentioned in section D.4.3, there were 32 zoning types defined in the RLC city zoning plan (current land use) across 13 zoning categories across the entire study area (Figure D.8). On the other hand, the RLC FDS spatial plans (future land-use scenarios) consists of 12 zoning types and only cover areas where potential developments may occur in the future scenarios. Spatial plan formats are often specific to the area and jurisdiction they are developed for. As such, categories for land use will vary within and across regions.

Figure D.8 RLC FDS spatial plan compared to current RLC city zoning plan



RLC FDS spatial plan (existing zoning attribute)

RLC city plan zoning information (type attribute)

In general, the zoning type referred to in the spatial plan is more generic compared to the ones used in the existing city plan. In most cases, where there are multiple zoning types within a small area in the city plan, the spatial plan has generalised the information to have a single zoning type.

A potential solution for the problem is to use the spatial plan from planners as the basis of analysis rather than the city plan zoning. This way, there is no need to map the city plan zoning types to the spatial plan zoning type. The downside of this approach is that the coverage of the spatial plan is a subset of the study area and its boundaries do not align with the census data. This makes incorporating its output to the sketch planning tool more difficult.

D.5.3.3 Some asset type profiles were derived from other assets (extrapolation required from other data sources)

The carbon footprint research used national RAMM data to derive asset profiles. For most asset types, the RLC RAMM data could be used directly to map assets to a profile and corresponding emissions factor. However, at the time of the carbon footprint research, some assets' RAMM data was either unavailable or inconsistent across regions.

For these assets, an indirect method was used to determine the number of assets within a region and profile type, in particular, bridges, pavements, markings, kerb and channel, catchpits and manholes.

At the time of the carbon footprint research, bridge data was not well maintained for RLC in RAMM. Instead, the NZTA bridge totals database was used to derive bridge emissions for Rotorua.

However, this database does not have the geospatial properties required to map assets to land use that is needed for the purpose of this research. Since this research paper began, the RLC bridge RAMM database has been updated and could now be used directly.

The remaining asset types are derived using a combination of treatment length RAMM asset data (which contains information for segments of roading) and ONRC. While the geospatial properties for the pavement data within RLC are good, the asset properties have large variations that would be difficult to map to a base set of profiles.

In addition, since the carbon footprint research, assets have been added or edited in the RAMM database. As such, there are some assets with a new type and composition that are not mapped to a profile. Some manual intervention will be needed to select the appropriate profile for these assets.

D.5.3.4 Deriving statistically significant relationships between asset composition and zoning types

From the preliminary analysis, the asset composition across different zoning types did not appear to be significantly different. This is partly due to the lack of standardised mapping methods between zoning types and assets. The resulting per-unit asset uptake included large outliers, which damped the strength of the relationship between assets and zoning type.

The issue may improve from resolving the problem where zoning types and assets are mapped to standardised geographical areas. However, some outliers may still need to be removed to ensure the outcome is unbiased for future application. This is likely a manual exercise that needs to be assessed on a case-by-case scenario.

D.5.4 Resolutions

D.5.4.1 Map city plan zoning information to the smallest geographic area definition possible (meshblock)

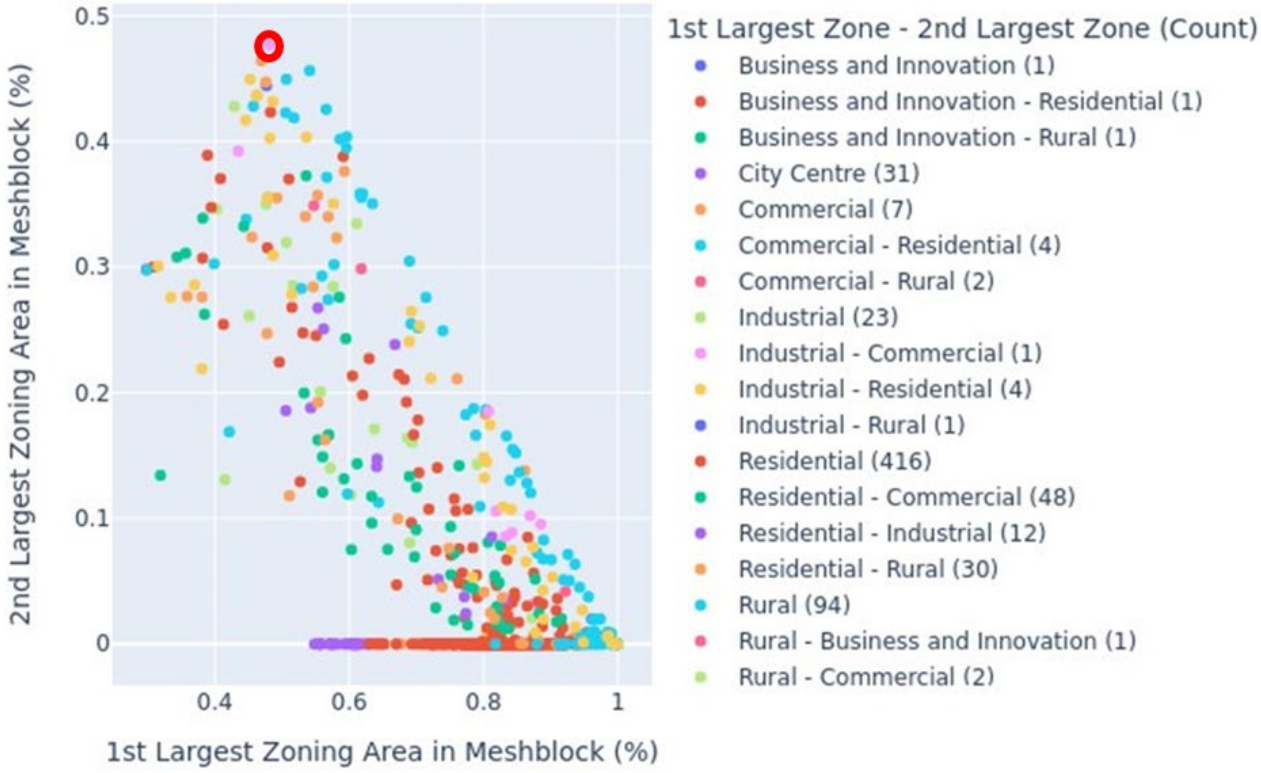
To overcome the challenges outlined by the RLC city zoning plan not covering the road carriageway space, a common standardised spatial area that covers the entire study area was instead used. The meshblock database, which is the smallest geographic unit reported by Stats NZ, contains 724 segments within the study area. This section covers the process of mapping the RLC city zoning land-use information to the meshblocks.

Of the 13 main zoning categories that exist in the current RLC zoning information, some are unlikely to be relevant to the future development (such as lakes). These were therefore removed during the mapping process, which reduced the total meshblocks in the mapping area by 7%.

Meshblocks are mapped to the RLC city zoning plan by taking the composition of zone categories that fall within the meshblock boundary. Some meshblocks have more than one zoning category. While most of them have a clear dominant zoning category, some may have two or more prominent zoning categories.

Figure D.9 depicts the first and second most prominent zoning category (by area coverage) in meshblock. For example, the pink point circled in red represents a meshblock that had 48% of its area zoned as rural and 47% as industrial.

Figure D.9 Percentage of first and second most prominent zoning category



To simplify this research, meshblocks with more than one prominent land-use type are removed from subsequent analysis. Moreover, some zoning categories had a small representation in the existing dataset (such as business innovation, as indicated by the count in brackets on the graph legend). Due to their potential bias, these meshblocks are also removed. At the end of data standardisation exercise, 74% of the total meshblocks within the RLC study area remained.

To test the impact of removing the meshblocks with mixed zoning categories, the emissions for each of these were estimated using the final methodology (estimation of asset compositions discussed below) and compared to the observed emissions (taken from the true composition of assets that fall within the meshblock). The meshblock was proportioned based on the percentage of each land-use type, which were then calculated independently. Using this approach for the example circled in Figure D.9, 48% of the total meshblock area is estimated assuming a rural land use composition and 47% industrial. The estimates were compared to the observed emissions from the RAMM assets within the meshblock. The results from the comparison between observed and estimated footpath emissions are summarised across all meshblocks with mixed zoning categories in Table D.3.

Table D.3 Accuracy of estimation methods across all mixed land use meshblocks

Observed total area	164,336
Estimated total area	174,307
Percentage error of estimated area	**~6%**
Observed total emissions	4,816
Estimated total emissions	5,305
Percentage error of estimated emissions	**~10%**

Table D.3 summarises the total difference in area and final emissions between the estimation method and observed across all mixed land use meshblocks. The estimation method performs relatively well, being within ~10% of the observed.

As the mixed land use meshblocks can be well estimated using the methodology, it is unlikely that including these meshblocks in the final methodology will change the final outputs. As such, they remain excluded from the subsequent analysis.

D.5.4.2 Define sample area for spatial planning zones – ask the planner to identify which existing area the high-density residential would build out to be

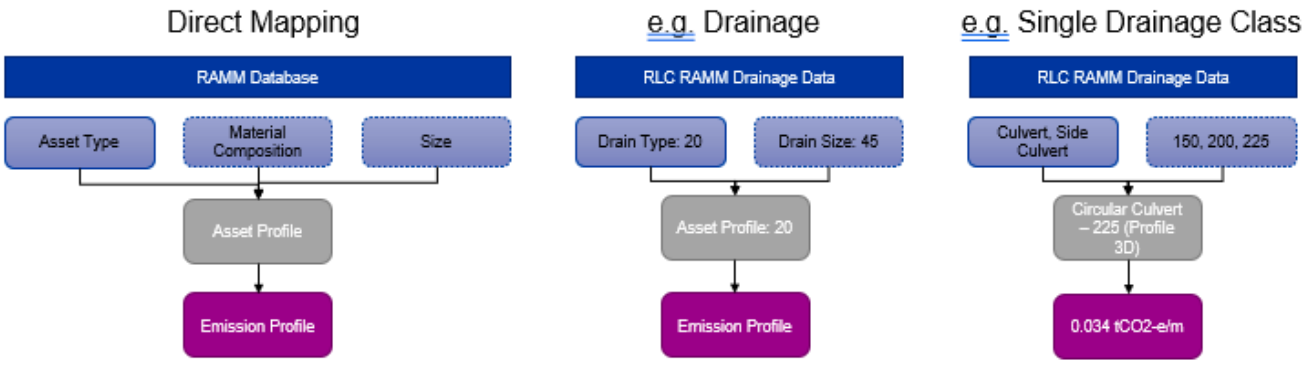
The second challenge is the difference between land-use definitions in the city plan zoning and spatial plan databases. With zoning type and asset data both mapped to meshblocks, the most accurate and easiest method is for the planner to identify which area the new regions would build out to be as opposed to going through the time-consuming exercise of mapping the individual area to all meshblocks.

D.5.4.3 Derive lookup for assumptions to be used by asset type and profile.

A lookup table mapping the RLC asset types to a profile within the carbon footprint research was finalised by mapping missing assets to profiles. This was achieved by manually checking the asset material compositions and confirming assumptions with subject matter experts.

For assets where RAMM data can be used directly to find the profile information, the process is as shown in Figure D.10.

Figure D.10 Process of mapping assets to profiles within the carbon footprint research

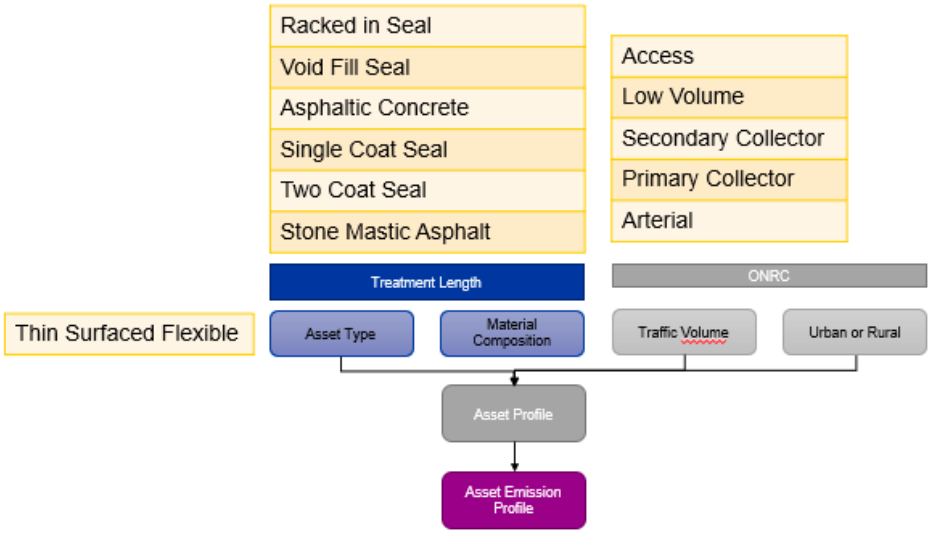


The plot on the left-hand side summarises the direct mapping process that maps RAMM data to an emissions profile. The centre plot shows a specific example of this for a single asset type – drainage. For RLC, there are 20 different drainage types and 45 different sizes. Rather than each of these having a unique asset profile, these are aggregated into 20 asset profile groups.

Asset profile groups have similar construction, size and material composition so are assumed to have similar emissions profiles. This is shown in the right-hand side plot. For example, culverts and side culverts of sizes 150, 200 and 225 are aggregated into the same asset profile group – Circular Culvert – 225 (Profile 3D). These assets will therefore have the same emissions profile – 0.034 tCO_2e/m.

For the assets where treatment length RAMM data and ONRC are instead used, the process is shown in Figure D.11. The carbon footprint research uses ONRC classifications and road type to assign an emissions factor. For pavements, road width and length are used to find the area. For markings, kerb and channel, manholes and catchpits, a unit per length of road factor is used.

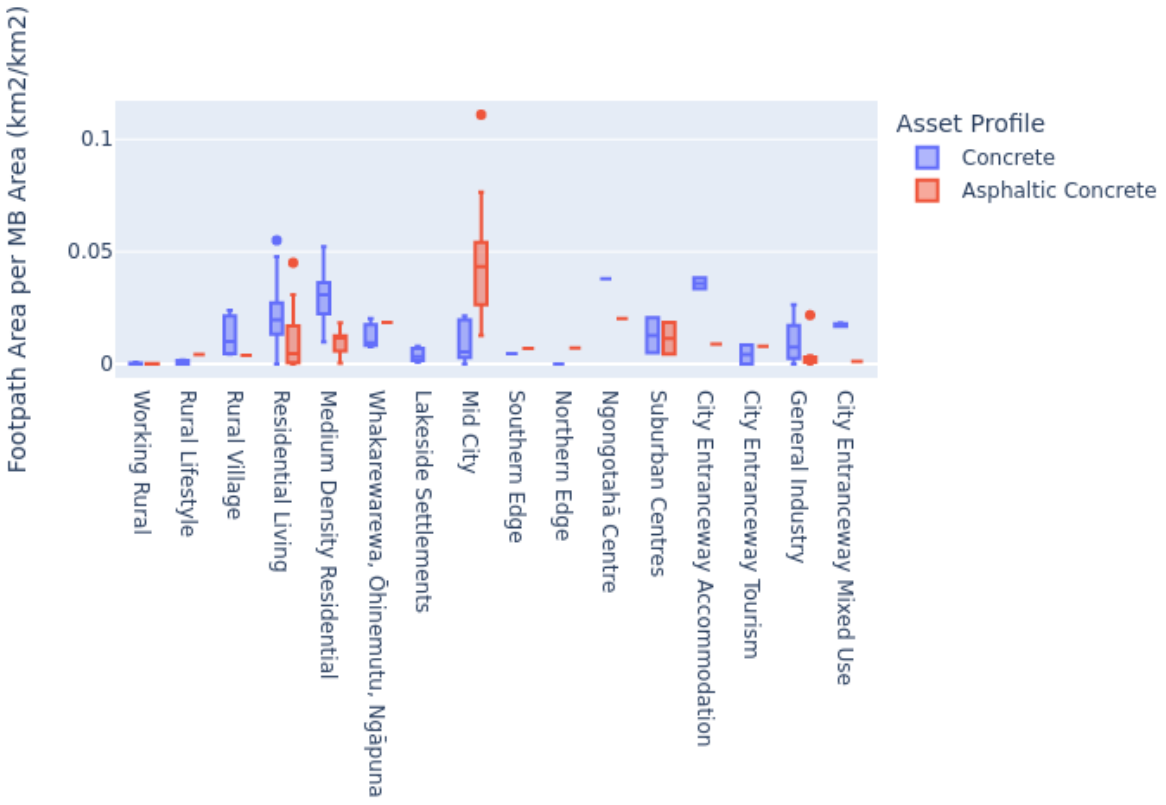
Figure D.11 Process of mapping assets to profiles using treatment length RAMM data and ONRC



D.5.4.4 Applying thresholds to remove outliers (so that the data is more statistically different between zoning types)

With the adjustments made above, deriving relationships between the meshblock land-use type and asset profile was still difficult. Figure D.12 shows the relationship between footpath profiles (for two of the five different profile groups to simplify the figure) and meshblock land-use type.

Figure D.12 Footpath profiles by meshblock land-use type



There is insufficient data to derive meaningful relationships at an asset profile and meshblock land-use level. Instead, we propose a two-fold approach to building this relationship – finding the asset coverage based on similar meshblock land-use types and then the composition of asset profiles across the entire zone.

D.5.4.5 Asset coverage

The process of finding the asset coverage involves determining the area of each asset type per land area within the meshblock, regardless of the asset profile. The meshblocks are then grouped by land-use type to derive a relationship between asset coverage and land use (Figure D.13 and Table D.4).

Figure D.13 Footpath coverage by meshblock land-use type

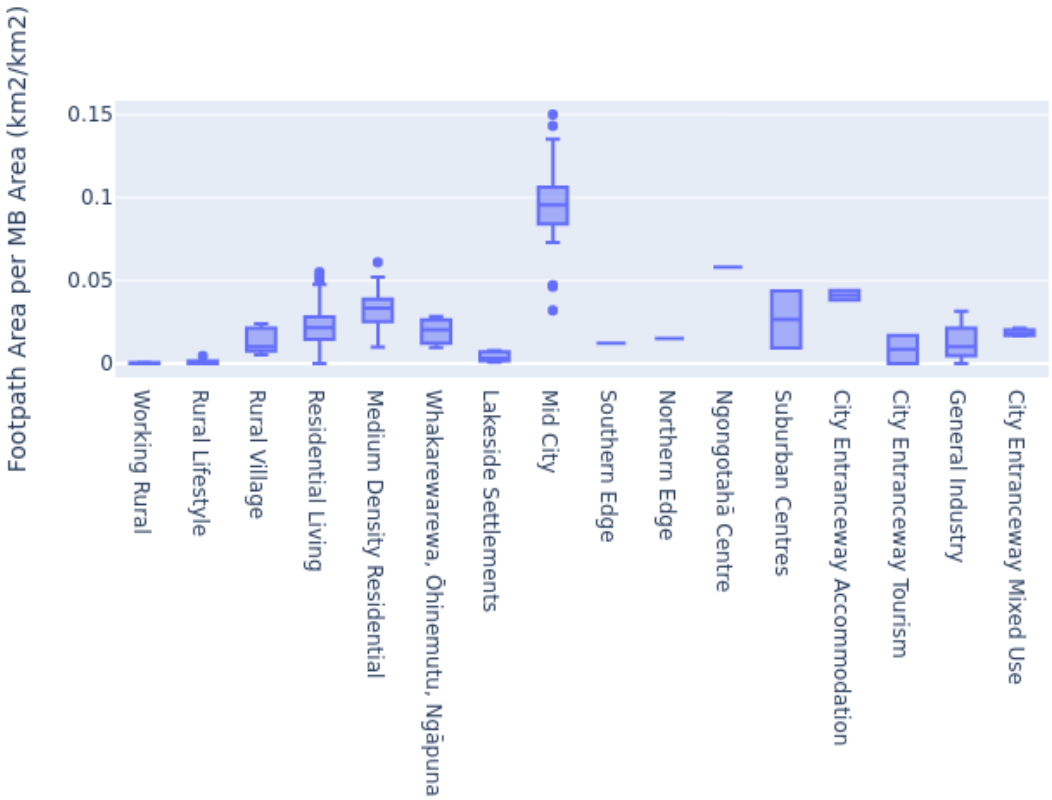


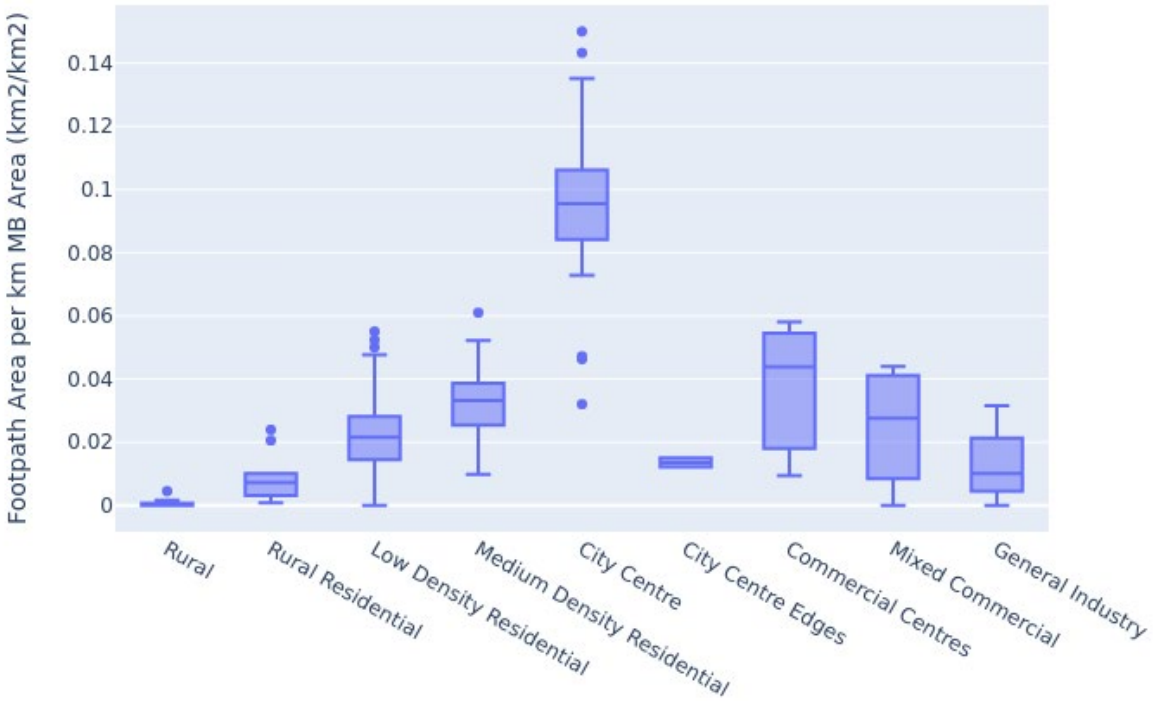
Table D.4 Count of meshblock land-use types (taken from footpaths)

Land-use type	Count of meshblocks
Working Rural	14
Rural Residential	6
Rural Lifestyle	5
Residential Living	360
Medium Density Residential	39
Whakarewarewa, Ōhinemutu, Ngāpuna	3
Lakeside Settlements	5
Mid City	29
Southern Edge	1
Northern Edge	1

Land-use type	Count of meshblocks
Ngongotahā Centre	1
Suburban Centres	2
City Entranceway Accommodation	2
City Entranceway Tourism	2
General Industry	16
City Entranceway Mixed Use	6

Two key issues are highlighted in Figure D.13 and Table D.4. The current meshblock land-use types have properties (and land use to asset relationships) that overlap with one another, and some land-use types have low sample sizes. For example, residential 1 and 3 have similar relationships in Figure D.9. These also have similar household densities when compared geospatially. City centre 2 and 3, as well as commercial 1 to 5 have low sample sizes that will be sensitive to bias. Rather than having these separate, meshblock land-use types should be aggregated into categories if they have similar compositions, particularly those with low sample sizes. This will help to develop stronger relationships. In addition, while the meshblock types have unique properties, this level of granularity is not required for the purpose of this tool. Future development scenario spatial plans are generalised into higher-level categories. Modifying the land-use types to reflect these is beneficial. The subsequent relationship plot is shown in Figure D.14.

Figure D.14 Footpath coverage by meshblock land-use category



Applying this aggregation strengthens the relationship between assets and land use. This approach was also tested on other key assets, including pavements, kerb and channel, manholes and catchpits. These assets as well as footpaths make up over 90% of the base year calculations. While footpaths are based directly on footpath RAMM data, the remaining four mentioned assets are calculated based on treatment length RAMM data, pavements using the area and the remaining using lengths. Therefore, these assets have similar relationships to land use – in particular, kerb and channel, manholes and catchpits are factors of each other. The relationship between pavements and land-use categories, and kerb and channel and land use, are shown in Figures D.15 and D.16 respectively.

Figure D.15 Pavement coverage by meshblock land-use category

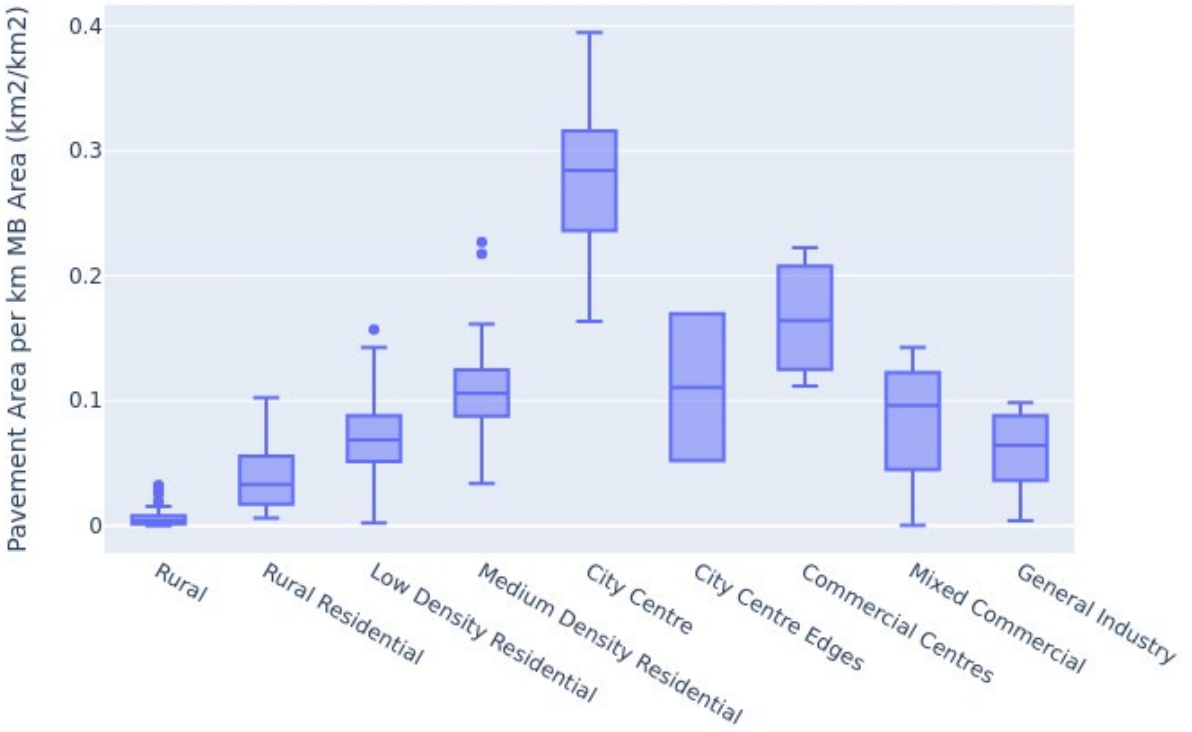
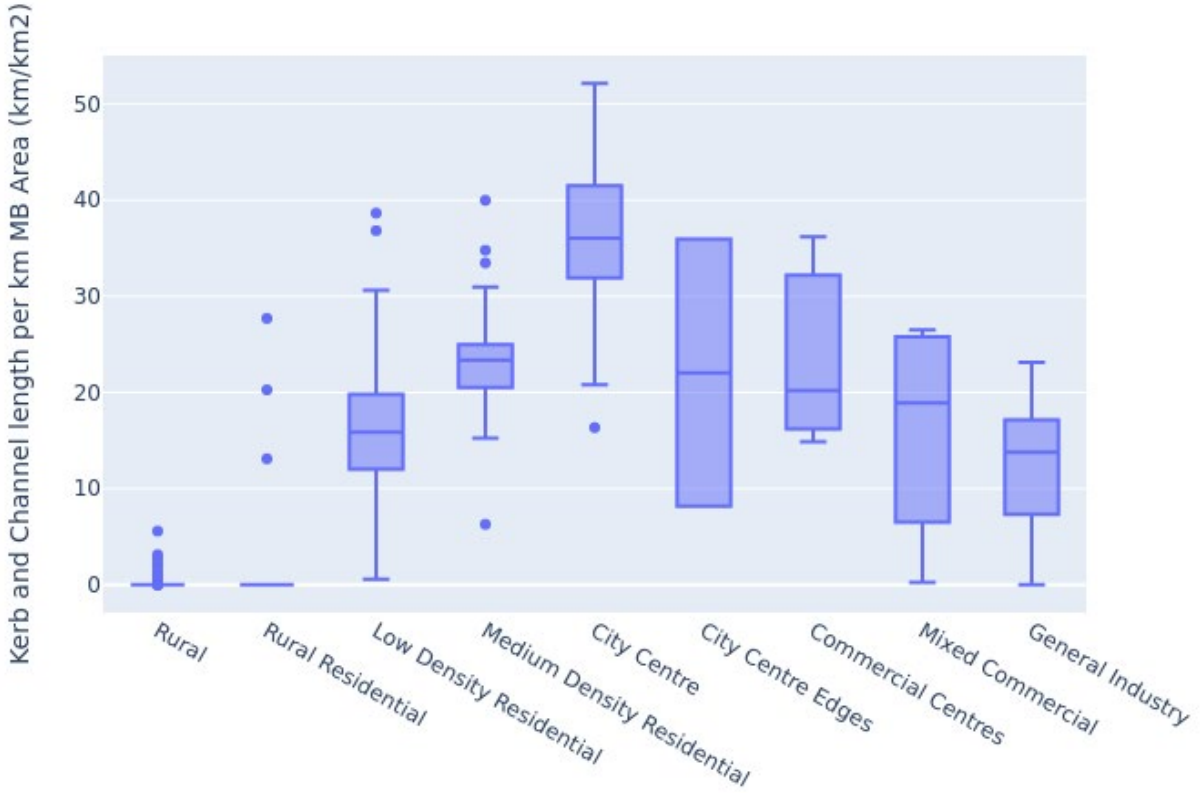


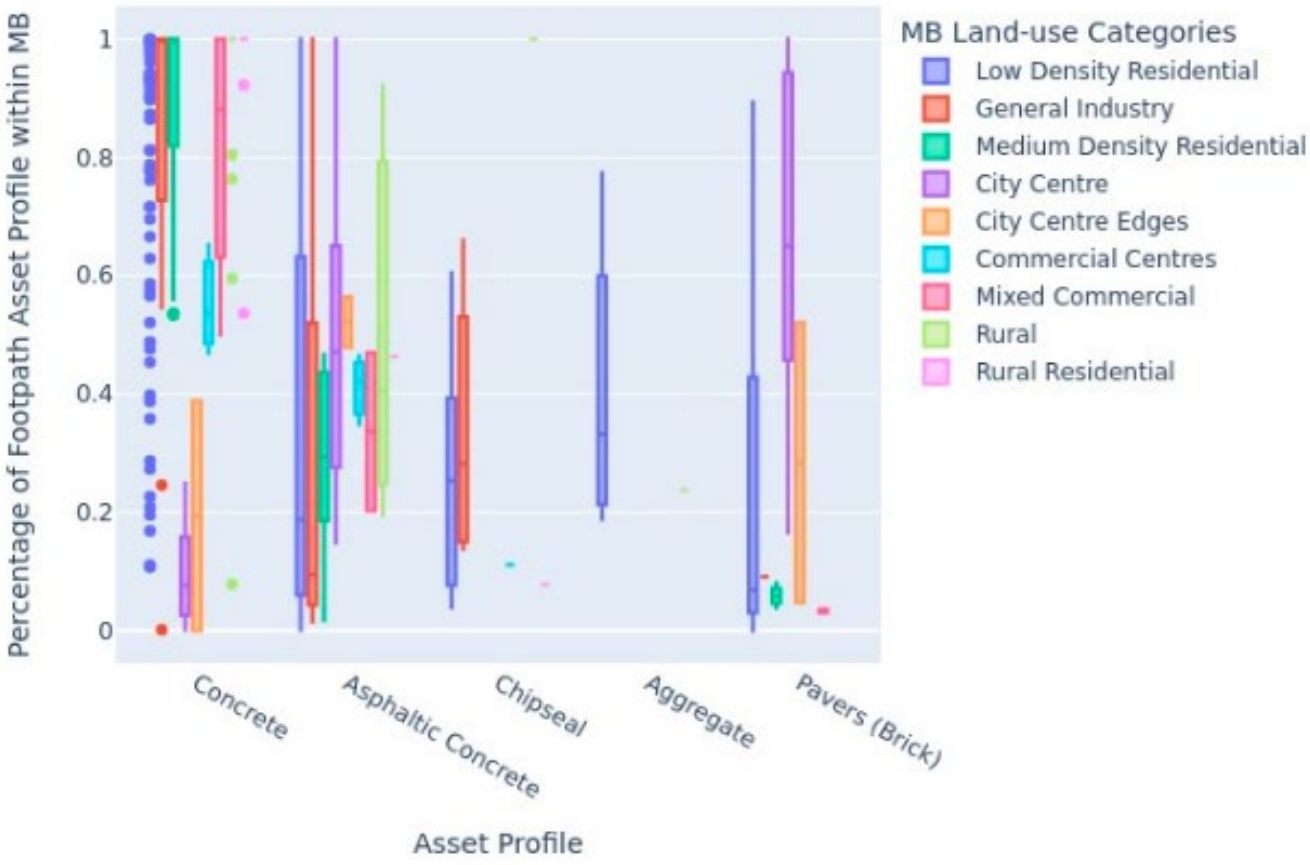
Figure D.16 Kerb and channel coverage by meshblock land-use category



D.5.4.6 Profile compositions

Once the asset coverage is determined using the above method, the composition of different asset profiles for each asset type is applied. Figure D.17 shows the asset profile and land-use category relationship for footpaths. Similarly to Figure D.12, there is insufficient data to derive a direct relationship. Instead, two methods were compared: taking the profile composition across all included meshblocks or taking the profile composition based on whether the meshblock was urban or rural.

Figure D.17 Footpath asset profile composition by meshblock land-use category



To compare the two methods, 50% of the meshblocks were selected and used to calculate the profile compositions. The estimated profile compositions were then applied to the remaining 50% of meshblocks. This was compared to the observed by calculating the upfront emissions. While maintenance, operational, and end-of-life emissions can also be calculated, only upfront emissions were compared for simplicity. The results of this comparison are shown in Table D.5.

Table D.5 Emissions after estimating profile compositions compared to observed

Method	Estimated emissions
Asset composition by meshblock land use	5,359
Asset composition across all meshblocks	8,102
Asset composition for urban and rural meshblocks	8,103
Observed	8,015

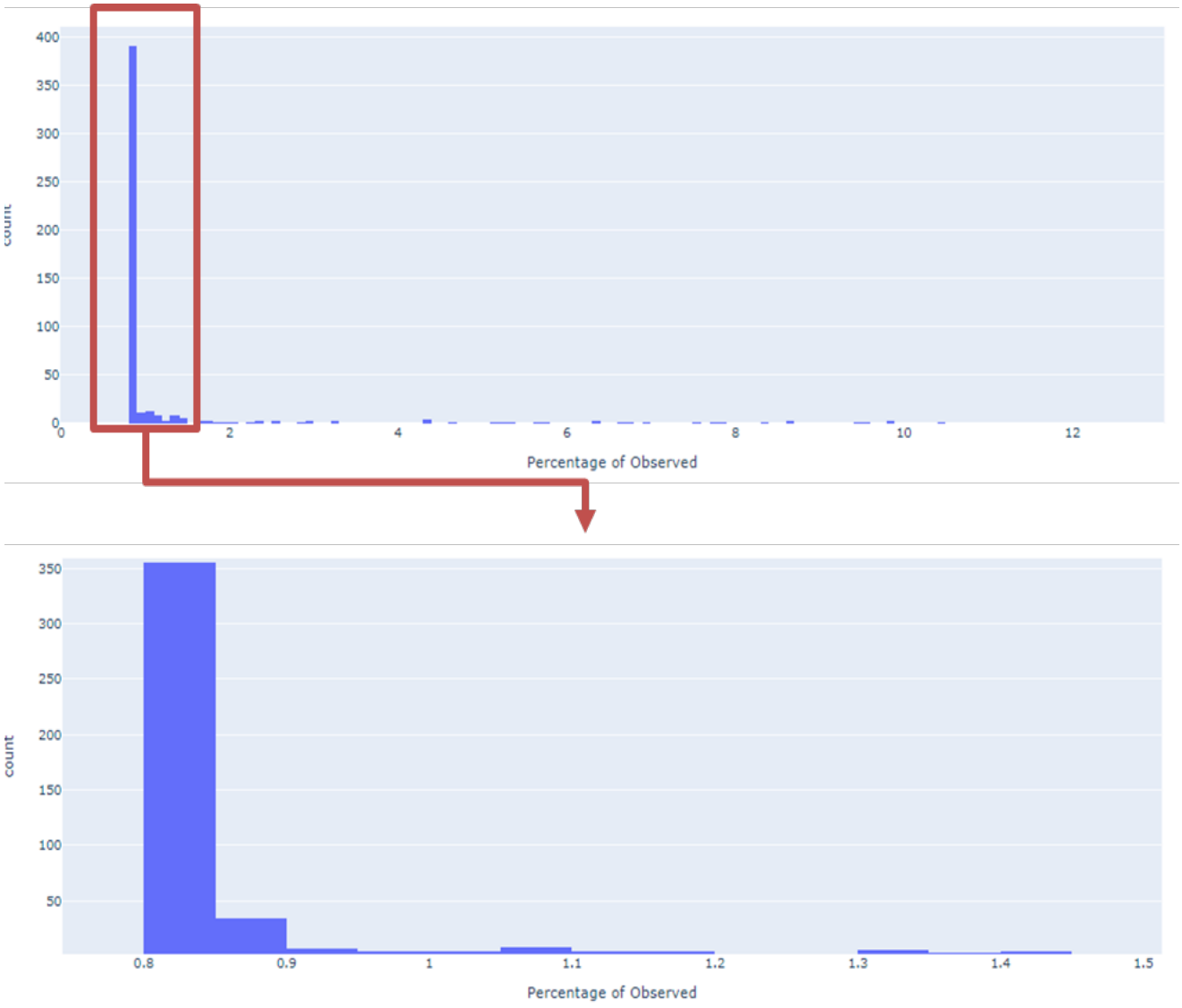
The lack of relationship at a meshblock level between land use and asset profiles is evident, with the estimation method being 33% less than the observed emissions.

On the contrast, applying a profile composition across the entire spatial area or by urban or rural land-use types produced similar final estimates that were close to observed.

While using urban and rural split for footpaths does not make a significant difference, assets based on treatment length were also largely dependent on whether the road was urban or rural. Using urban and rural is still effective across all assets but performs better across assets that are dependent on whether the treatment length is urban or rural.

Figure D.18 shows the variability of footpath emissions from observed at a meshblock level as a direct effect of estimating the profile compositions. While there are some outliers, 86% of the meshblocks are within 20% of the observed emissions.

Figure D.18 Variation at a meshblock level between estimated footpath emissions and observed



D.5.4.7 Combined

The recommended approach involves estimating the asset coverage based on the land-use category before applying a profile composition that is dependent on whether the meshblock is urban or rural. As this approach is two-fold, the errors may compound. Asset coverage and profile composition across all meshblocks were used to estimate upfront emissions at a meshblock level and compare these against observed.

The first two rows of Table C.6 show the percentage error between the total estimated asset coverage and embodied emissions compared to the observed. As kerb and channel, manholes and catchpits have all been estimated using the same RAMM data (treatment length), they have the same degree of error. Outside of these assets, error varies between each. Pavements has the largest degree of error, with the estimated emissions being 52.4% greater than what is observed. The remaining key asset types overestimate embodied emissions by ~15%.

Table D.6 Sensitivity of estimation method against observed for five key asset types

	Footpaths	Pavements	Kerb and channel	Manholes	Catchpits
Percentage error of estimated asset coverage	15.6%	55.8%	13.9%	13.9%	13.9%
Percentage error of total estimated emissions	15.7%	52.4%	14.4%	14.4%	14.4%
25 percentile at meshblock level	-31.3%	-19.5%	-18.1%	-18.1%	-18.1%
50 percentile at meshblock level	-4.1%	7%	3.6%	3.6%	3.6%
75 percentile at meshblock level	69.5%	48.4%	36.9%	36.9%	36.9%

The final three rows of this table show the percentage error between estimated embodied emissions and observed on an individual meshblock level. The 25 percentile indicates that the lower 25% of the meshblocks have a percentage error that is less than the stated percentage. The 50 percentile indicates the accuracy of the median meshblock. The 75 percentile indicates that the upper 25% of meshblocks have a percentage error that is greater than the stated percentage. This data shows that, while the median meshblock produces reasonable estimates of reality, there is significant variation on a meshblock level.

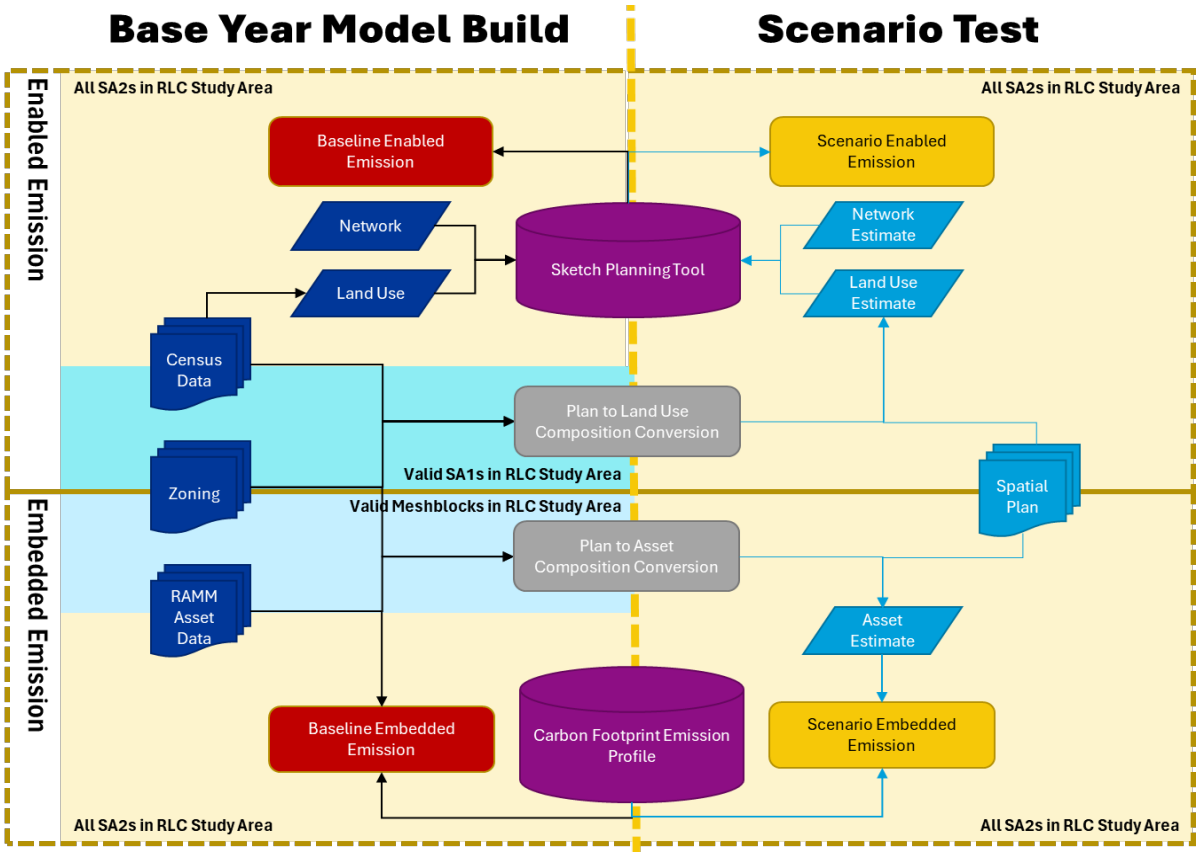
While the emissions estimates for footpaths are reasonable when looking across the entire study area (15.7%), at a meshblock level, there is a large spread in accuracy. For the middle 50% of meshblocks, the percentage error varies between -31.3% and 69.6% – a variation of over 100%. This indicates that, while the assumptions behind this research could be used to give an indication of embodied emissions across the entire area, the assumptions are not granular enough to produce accurate estimates on a zonal level.

D.5.5 Refined methodology

The refined methodology follows the same structure as the one originally proposed but with added interim steps where spatial plans, zoning information and asset data are mapped to standard baseline geographic units.

Furthermore, as mentioned in previous sections, the successful implementation of the tool for scenario tests needs to be built on a well-calibrated base year model. Therefore, the refined methodology for assessing enabled and embodied emissions is summarised in Figure D.19.

Figure D.19 Refined methodology for expansion of the sketch planning tool to include embedded emissions



D.5.5.1 Plan to asset composition

The approach to mapping land use to assets is two-fold: estimating asset coverage based on land-use category before applying a profile composition that is dependent on whether the meshblock is urban or rural. The asset coverage was selected based on the median unit per km across each meshblock and profile composition based on the total proportion of each asset profile across all urban and all rural meshblocks (Table D.7). In a similar way, a lookup table for the asset profile compositions across urban and rural land-use types is generated for each asset. These can be applied to future land-use scenarios to determine an approximate estimate of the horizontal asset composition and embodied emissions.

Table D.7 Median asset coverage for five key asset types

	Footpaths (km^2/km^2)	Pavements (km^2/km^2)	Kerb and channel (km/km^2)	Manholes (km/km^2)	Catchpits (km/km^2)
City Centre	0.0956	0.0284	36.050	20.028	20.028
City Centre Edges	0.0136	0.1101	22.053	12.252	12.252
Commercial Centres	0.0434	0.1644	20.190	11.217	11.217
Mixed Commercial	0.0277	0.0964	18.925	10.514	10.514
General Industry	0.0101	0.0645	13.758	7.643	7.643
Low Density Residential	0.0215	0.0685	15.879	8.821	8.821
Medium Density Residential	0.0332	0.1059	23.369	12.983	12.983
Rural	0.0001	0.0039	0	0	0
Rural Residential	0.0072	0.0330	0	0	0

D.5.5.2 Plan to land use conversion

Spatial plans for four development scenarios were provided consisting of dwelling yield and industrial business land area for individual development areas. As per the specification provided by the planners, for each scenario:

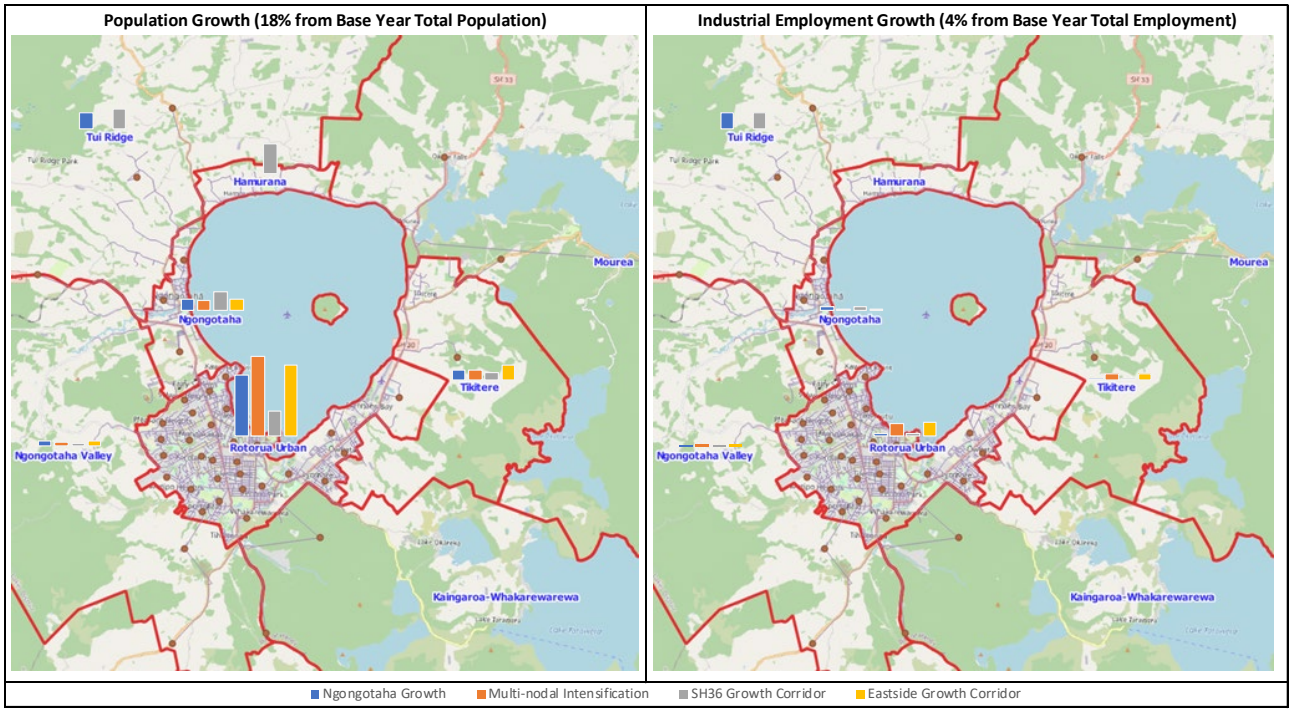
- the dwelling yield should capture all the population growth in the area
- only industrial employment growth is captured by the industrial business land area.
- Ngongotahā region has a new primary school for scenario 1 (Ngongotahā growth) and 3 (SH36 growth corridor).

These development areas were mapped to TAZs and used to distribute future land-use projection. The following data sources are used to benchmark the future land-use projection:

- Census household and population projection for SA2s inside the study area for 2048, which is used to control the total population in the study area. Dwelling yield is converted to households based on dwelling to household rate calculated from census data in the study area.
- Employment projection published in the Rotorua Housing and Business Development Capacity Assessment 2021 Technical Report, which is used to control total future employment growth by category in the study area.
- It is assumed that the school roll would increase proportionally to the population growth.

Across all scenarios, the total population and employment growth in the model is identical but the growth of population and industrial employment are distributed differently depending on the scenario. Comparing to the base year, the overall population growth is about 18% while the industrial employment growth is about 4%. Figure D.20 depicts the distribution of the population and industrial employment growth in the study area, where the bars indicate the percentage growth from base year.

Figure D.20 Distribution of the population and industrial employment growth in RLC



D.5.5.3 Tool outputs

Once the relationship between urban form and travel demand is established, the tool can be used to test future spatial plans for specific land-use interventions. This section presents some example outputs of the sketch planning tool generated as part of the RLC FDS project, which show the relationship between land use and enabled emissions.

Figure D.21 shows the base year daily enabled emissions for cars across Rotorua. For future scenarios, results are output in comparison to a base scenario to indicate the scale of enabled emissions changes in response to a specific land-use intervention. The base scenario is business as usual, which assumes that population growth is spread evenly across the entire study area without any specific land-use interventions.

Figure D.21 Base year daily enabled emissions from cars

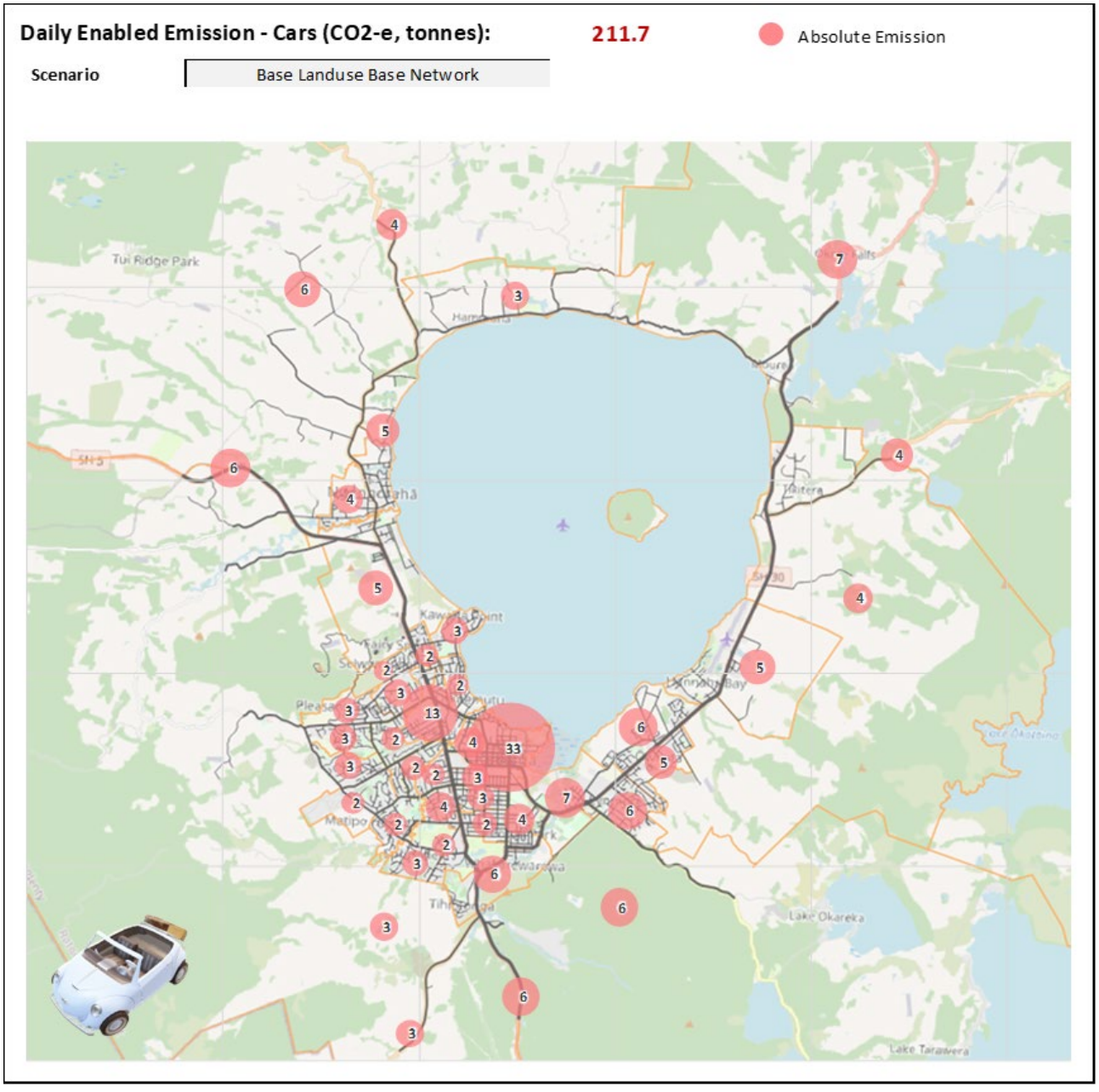
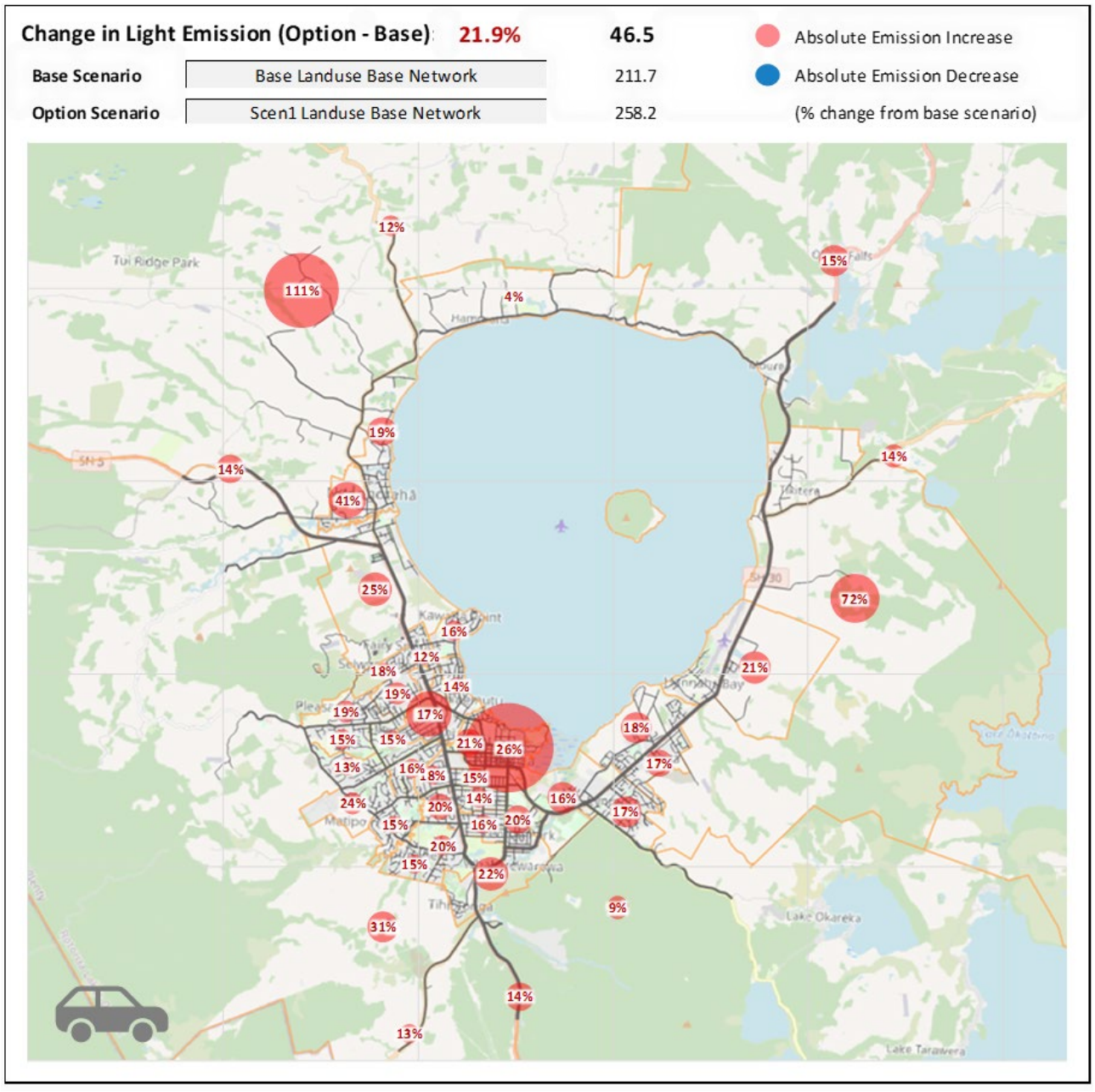


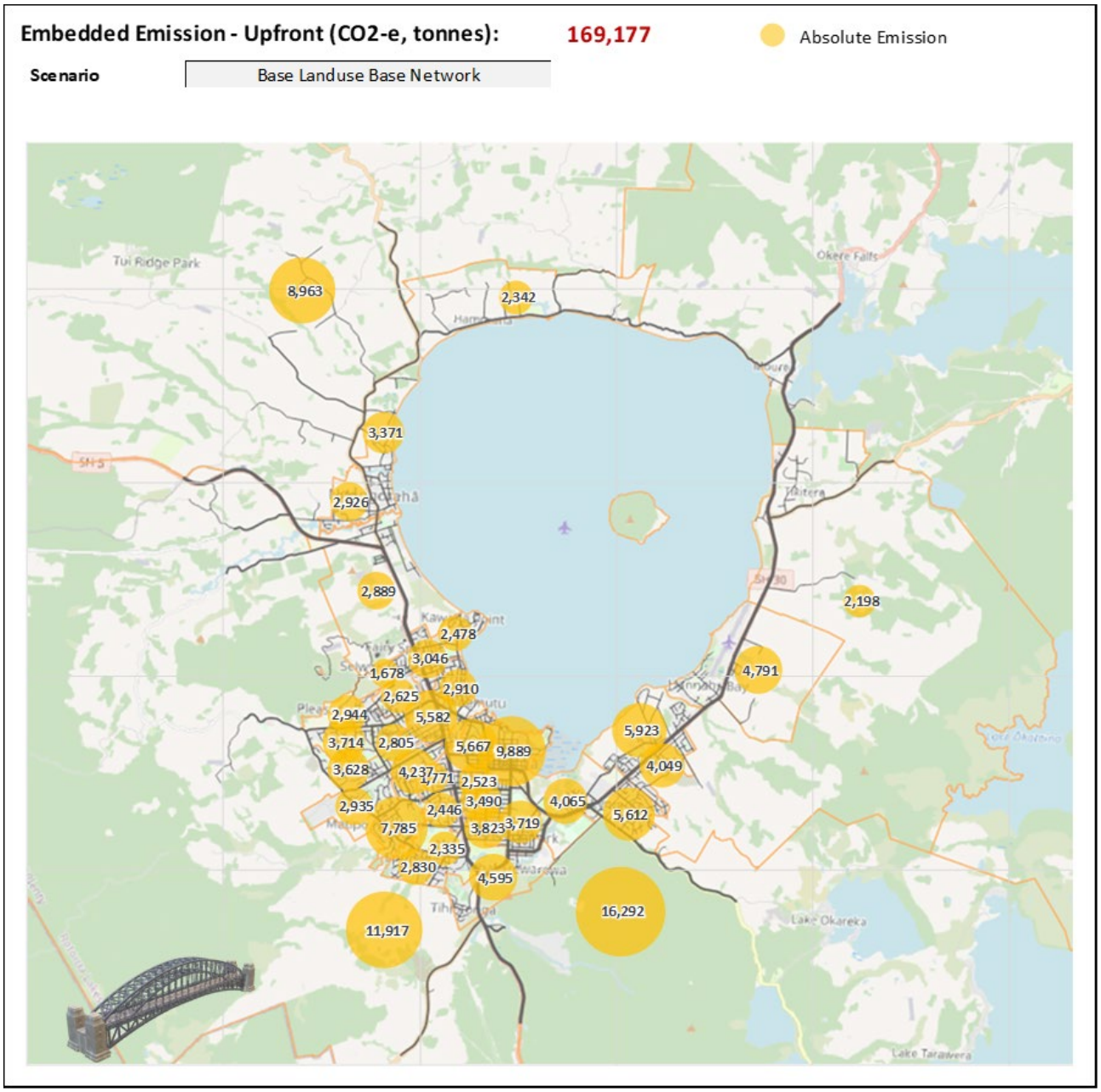
Figure D.22 shows how the tool can be used comparatively between two scenarios. This example compares enabled emissions for light vehicles for where a housing development is built in the Ngongotahā area in comparison to the base scenario.

Figure D.22 Light enabled emissions change from the base to Ngongotahā growth scenario



In a similar way, the sketch planning tool can produce outputs that show the relationship between land use and embodied emissions. The upfront (emissions associated with the construction of assets) embodied emissions for the base year where observed RLC RAMM data is available and the carbon footprint research recently conducted are output in Figure D.23. While embodied emissions estimates are reasonable when looking across the entire study area, at a zonal level, there is a large spread in accuracy. As such while the tool can produce outputs at a zonal level to compare embodied emissions between future scenarios, these were not generated as accuracy at this level cannot be guaranteed.

Figure D.23 Base year upfront embedded emissions



D.6 Conclusion

In this research on sustainability assessment of urban form and transport relationship, we explored a potential method to estimate transport-related sustainability impacts from different spatial plan scenarios that combined estimates of embodied carbon by land-use type with enabled estimates from the sketch planning tool. As highlighted in the introduction, our research does not set out to supplant existing transport models used in evaluation processes nor more detailed carbon assessments for specific proposals. Rather, we are exploring the potential of an additional methodology that could build a simpler relationship between transport emissions and urban form. The sketch planning tool attempts to fill the need for a tool that has a solid technical base but is still generic enough to generate outputs quickly from a simple set-up. This research investigated methods to estimate both enabled and embodied emissions from spatial plans consisting of various urban forms using the sketch planning tool.

To estimate enabled emissions, the sketch planning tool follows procedures similar to those outlined in the transport model development guidelines from NZTA.

This includes the development of a base model representative of the transport response to high-level travel demands resulting from the existing city urban form. The development and verification of the base model is achieved through comparisons of modelled information with observed travel data. This included census journey to work and journey to education data, traffic counts on key routes and overall VKT in the study area.

Once the base model is calibrated, the inputs can be adjusted for the testing of the RLC FDS spatial plans with different urban forms. Initial attempts were made to derive a quantitative relationship between zoning type (existing urban forms) and land-use density (such as full-time employment per hectare for light industrial zones). However, preliminary analysis revealed inconsistencies between the different land-use definitions between the zoning type (existing state urban forms) and the future spatial plans (proposed future state urban forms). For example, the existing urban form zoning information includes the land-use type industrial 1 (general industry), where the closest match within the proposed future spatial plan is light industrial. These differences make deriving a simple relationship between zoning type and land-use density from base year data that can then be applied to the future spatial plans difficult and unreliable.

To overcome this, for the RLC FDS, a simpler approach was agreed and adopted alongside spatial planners. Rather than using a bottom-up approach where land-use density by urban form data derived from base year information is applied to the future spatial plans, the overall projected growth was instead calculated for the entire study area. The future spatial plans were then used to distribute the overall projected growth spatially. Combined with background growth assumptions (changes that are expected regardless of the specific scenario being tested), the spatial plans are converted into land-use inputs for the sketch planning tool to produce key transport-related outputs. The VKT estimated from the tool is converted to enabled emissions by applying emissions factors from the VEPM (Waka Kotahi NZ Transport Agency, 2023d), a model developed by NZTA and Auckland Council to predict emissions from vehicles in the New Zealand fleet.

To estimate embodied emissions from transport infrastructure within the sketch planning tool, this research explored incorporating the method used within the carbon footprint research.

- The carbon footprint research calculates embodied emissions for horizontal infrastructure within the RAMM dataset, which contains key information and attributes on roading infrastructure and assets. RAMM data is available nationally with approval from the roading ownership body. Standardised emissions factors from PEET are aggregated to create emissions profiles based on the assumed material composition and construction of key RAMM infrastructure types. Rather than each asset having a unique emissions profile, emissions profiles represent a standardised infrastructure asset (assets of similar composition share an emissions profile). The emissions profiles are intended to cover whole-of-life emissions from construction to end of life, excluding operational emissions from user operation (enabled emissions).
- For the base model, the latest RAMM data for Rotorua (existing horizontal infrastructure database) was mapped to the study area and each RAMM asset to its respective emissions profile group within the carbon footprint research. The emissions profiles were then applied to the RAMM data to calculate the embodied emissions for the existing urban form.
- For the testing of the RLC FDS spatial plans, initial attempts were made to quantify the density of assets within the existing urban form types, which could then be applied to the future scenarios. To strengthen the relationship between assets and zoning type, RAMM assets were aggregated into their emissions profile groups and zones with mixed land-use types were excluded. The result was a factor of the asset profile groups for each zone type on an asset unit per zone area basis (area of footpath per square metre of urban form). When the resulting function is applied to the zoning information, the estimated unit of assets within each zone for the key asset types analysed are generally higher than what is observed.

- For the RLC FDS implementation, the asset per zone type area relationship was derived for five key asset types (footpaths, pavements, kerb and channel, manholes and catchpits) using the base year RAMM and zoning data. These assets were selected as they contribute the most significantly to embodied emissions. These relationships were used to convert spatial plans for residential and industrial growth for RLC FDS into the expected asset coverage growth to support the changing urban form (increased density of roading infrastructure would be expected to facilitate intensification). The emissions profiles from the carbon footprint research are applied to the estimated asset coverage to calculate embodied emissions in the study area.