Latent demand for walking and cycling

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Abbreviations and acronyms

AADT	annual average daily traffic
ACCPDM	Auckland City Centre Pedestrian Demand Model
ACM	Auckland Cycle Model
ARCM	Abley Route Choice Metric
CAU	census area unit
CSCM	Christchurch Strategic Cycle Model
CyIPT	Cycling Infrastructure Prioritisation Toolkit
EEM	*Economic Evaluation Manual*
GIS	geographic information system
GPS	Global Positioning System
LTNZ	Land Transport New Zealand
MoPeD	Model of Pedestrian Demand
MSPM	Modified Stated Preference Method
PCT	Propensity to Cycle Tool
PIE	Pedestrian Index of the Environment
SAMM	(Auckland) Strategic Active Modes model
SF-CHAMP	San Francisco Chained Activity Modeling Process
SFCTA	San Francisco County Transportation Authority
STEM	Strategic Transport Economic Model
TAZ	Transport/Traffic Analysis Zone
TCM	Tauranga Cycle Model
TTM	Transtheoretical Model (of Intentional Behaviour Change)
WCDM	Wellington Cycle Demand Model
WTSM	Wellington Transport Strategy Model

Contents

Executive summary

Why was this research needed?

Various methods exist that attempt to identify and measure latent demand, or the 'untapped potential', for walking and cycling, as well as to aid understanding of how improved provision for walking and cycling may realise a portion of latent demand. However, estimating latent demand for walking and cycling is an emerging science in New Zealand, with limited research into the application and effectiveness of the different methods employed around the country over the past decade.

What was the purpose of the research?

Firstly, this research sought to understand how latent demand for both walking and cycling is currently estimated in a range of New Zealand and overseas settings. Secondly, it sought to describe preferred approaches that could be adopted nationally in New Zealand and recommend a method for developing and testing estimates of latent demand.

How was the research conducted?

Firstly, a targeted review and summary of the literature was used to identify the range of factors associated with walking and cycling travel behaviour and behaviour change. Next, methods for estimating latent demand were identified through a review of the literature, as well as through a stakeholder and practitioner survey that was distributed within New Zealand and internationally. Follow-up interviews were employed with some survey respondents as required. The latent demand estimation methods were assessed based on the findings of this process, as well as the findings of the walking and cycling behavioural review. The findings were presented as a stocktake of the range of methodologies used over the last decade to estimate latent demand for walking and cycling.

Secondly, findings from the first stage were used to create a decision tree to guide practitioners towards the most fit-for-purpose methods to estimate latent demand for walking and cycling. The first stage also identified the need for, and initiated the development of, a walking and cycling demand case study database to help walking and cycling demand forecasting in New Zealand. This involved developing the database fields (presented in a spreadsheet format) and populating the database with an initial set of case studies.

What did the research find?

Walking and cycling behaviour and behaviour change

How infrastructure changes affect individuals and communities is a reflection of many factors, as well as the intended intervention itself. The implication of this for walking and cycling latent demand estimation methods is that the transferability of data, factor associations, and parameters between places must be assessed carefully. While the determinants of walking may overlap with those for cycling in some instances, they diverge in others, and the strength of associations varies between modes. Methods for estimating latent demand for walking and cycling must therefore consider the modes separately in order to adequately represent them.

Stocktake of methods for estimating latent demand

The past decade has seen substantial progress made to develop the range and quality of methods used to forecast latent demand for walking and cycling. It has also seen efforts made to better incorporate insights from research into walking and cycling behaviour and behaviour change. As expected, this research found that methods to forecast demand for cycling were far more abundant and tended to be more advanced than those for walking. Additionally, the information available about the various methods, their application, and their evaluation is highly variable. As a result, it is challenging to make a thorough assessment and comparison of many of the methods. Despite the recent progress that has been made, there was a general level of caution among respondents as to the reliability of walking and cycling forecasts, with some commenting that transportation forecasts in general are not seen as highly credible (for any mode).

A conceptual framework was proposed to assess latent demand estimation methods based on what goes in, the process it goes through, and what comes out. This led to the categorisation of latent demand estimation methods for walking and cycling into groups. These categories, and briefly summarised assessments, are listed below.

- **Pragmatic approaches**
  - Tend to be quick and cost effective, employing data at hand, and adaptable to fit the purpose. Generally seen as having inconsistent accuracy.
  - Tend to be used for smaller scale and budget applications.
- **Demand typologies**
  - Useful for understanding demand and latent demand characteristics across a population.
- **Stated preference based**
  - Useful for testing perceptions, and the potential behavioural response of those people with latent demand for walking and cycling, or to infrastructure that is new (ie, where there is no data on how it may be used).
  - Can be seen as unreliable and prone to bias.
  - May be best used in combination with other data (ie, revealed preference data).
- **Revealed preference based**
  - Tend to be seen as being more reliable than stated preference.
  - Have limitations when real choices are constrained, applied to latent demand, or something new.
- **Traditional transport models**
  - The accuracy of any model is dependent on the quality of data and the robustness of the parameters of the model.
  - May not readily account for behavioural ‘tipping points’ or changes in system dynamics.
  - Applications for cycling are much more advanced than for walking.
  - Capable of representing complex land use and transport interactions and trends over time, and multimodal transport systems at a network level.
  - Various enhancements possible to better represent walking and cycling behaviour.
  - Data and technology intensive.
- **Geospatial assessments**
  - Capable of integrating a wide range of complex geospatial information (including output from transport and other models) to form a comprehensive, multi-criteria assessment of walking and cycling demand.

  - Can be (but not always) more data and technology intensive.

Six core themes related to limitations and cautions of latent demand forecasts emerged from respondent feedback in the survey and interviews:

1. **The potential to reflect and exacerbate inequities**: Walking and cycling demand forecasts may reflect existing patterns of transport system inequity, and therefore basing investments on them risks potentially further exacerbating inequities.
2. **Balancing forecasting effort versus value**: The importance of balancing the effort and cost of producing a reliable demand forecast with the value it provides.
3. **Knowledge and data limitations**: The major constraint in producing quality walking and cycling demand forecasts is a lack of knowledge and data.
4. **The unknown future**: Many forecasts cannot readily and reliably account for factors of the unknown future, such as new technologies and changing preferences.
5. **Forecast evaluation limitations**: Where evaluation either does not occur or is constrained.
6. **Predicting and providing versus setting a target**: Some respondents challenged the role of demand forecasts that project past trends to see ‘what is possible’ in the future, instead advocating that decision making should be vision-based, where the decision is made to achieve a particular result or target and a plan is made to achieve it.

Recommendations

The following recommendations are made based on the research findings.

Improved data collection and sharing

- Efforts should be made to continue to improve the routine collection and sharing of quality walking and cycling count data across New Zealand, including establishing data standards and funding and contractual mechanisms to promote collection.
- Consider the upkeep and development of the database of walking and cycling facilities and counts.

Improved demand forecasting guidance

- Consider target-setting leading the forecast: setting a strategic target based on mode share, level of service, amenity, equity, or safety, and then using forecasts to prioritise facilities in reaching the target.
- Consider promotion and use of the decision-tree approach.
- Consider updating the New Zealand cycling sketch plan procedure.
- Ensure that transport modelling guidance in New Zealand is suitable for walking and cycling models.
- Consider pilot projects validating or adapting successfully tested open-source software tools, such as the Cycling Infrastructure Prioritisation Toolkit (CyIPT) and the complementary Propensity to Cycle Tool (PCT).

Advancing the state of practice

- Encourage the sharing of methods, strengths, weaknesses and assessments to improve the state of practice and sense of legitimacy in New Zealand, such as peer review, mentoring, and workshops.

Transparency and consistency

- Encourage demand forecasts to be produced with transparency around their assumptions (and the effect of these) and limitations.

Abstract

Estimating latent, or suppressed, demand for walking and cycling is an emerging science in New Zealand, with limited research into the application and effectiveness of the different methods employed around the country over the past decade. This first stage of this research employed a literature review, and a survey and interviews of practitioners, to understand how latent demand for both walking and cycling is currently estimated in a range of New Zealand and overseas settings. It then assessed how well these methods incorporate data and research about existing travel behaviours and travel behaviour change, and their accuracy as determined by post-implementation count data (where possible). The second stage of this research employed the findings from stage one to create a decision tree, or framework, indicating approaches that could be adopted nationally in New Zealand for greater consistency in walking and cycling demand estimation. It also identified the need for, and initiated the development of, a walking and cycling demand case study database to aid the practice of forecasting walking and cycling demand in New Zealand. This research found that the past decade has seen substantial progress made to develop the range and quality of methods used to forecast latent demand for walking and cycling. It has also seen efforts being made to better incorporate insights from research into walking and cycling behaviour and behaviour change. As expected, it was also found that methods to forecast demand for cycling were far more abundant and tended to be more advanced than those for walking. Additionally, the information available about the various methods, their application, and their evaluation is highly variable and inconsistent.

1 Introduction

1.1 A brief introduction to the concept of latent demand

Clifton and Moura (2017) conceptualise latent demand simply as the ‘currently desired demand’ for travel and activities ‘that is not realized because of a wide variety of constraints’ (p. 79). Accordingly, changes or improvements to the transport system can induce or realise a portion of this latent demand. Clifton and Moura (2017) suggest latent demand can be realised in two main ways: firstly as a redistribution of existing travel, which can be as a change in spatial or temporal travel patterns, or a change in travel mode, frequency or destination; and secondly as generative demand, which is the realisation of previously suppressed travel or unmade trips. They also point out that the distribution of latent demand across a population may not be evenly spread, with ‘those bearing the greatest consequences of suppressed demand’ being likely to be ‘the poor, elderly, those with physical and mental limitations, communities of colour, and other disadvantaged populations’ (Clifton & Moura, 2017, p. 78). Given that latent demand is likely to be distributed unevenly and in a way that may compound other inequities, it seems appropriate that investigations into latent demand should also consider inequities.

A latent (or suppressed) demand for walking and cycling can exist within people who currently exhibit little or no walking or cycling behaviour. It can also exist within people who do already walk or cycle but would do so more often if provisions for these modes were improved. For example, people may walk and cycle for some trips, to some places, some of the time, but may like to walk or cycle for more (or new) trips, to more places, more of the time, if they felt enabled to do so due to some relevant improvement. Additionally, even people who walk or cycle at their current maximum capacity can have a latent demand for improvements to walking and cycling provision. Improved provision may not always encourage them to walk or cycle more often, but it may improve their walking or cycling experience, such as through increased feelings of safety or comfort, or through a sense of legitimacy and being valued by society. An improved experience for people currently walking or cycling may then enable or encourage them to continue to do so into the future, perhaps over the various stages of their lives. For example, it has been shown that improvements in walking or cycling provision can arrest an overall trend of decline in levels of walking or cycling (Keall et al., 2015). A stabilising of levels of walking or cycling through the provision of improvements may not always appear to have realised a latent demand for these modes, unless it is appropriately viewed within the context of a declining overall trend.

1.2 The role of latent demand assessments

Various methods exist that attempt to identify and measure latent, or the ‘untapped potential’, demand for walking and cycling, as well as to aid understanding of how improved provision for walking and cycling may realise a portion of latent demand. High quality walking or cycling demand forecasts provide essential evidence for both network planning and investment cases. However, estimating latent demand for walking and cycling is an emerging science in New Zealand, with limited research into the application and effectiveness of the different methods employed around the country over the past decade. Additionally, different sized towns and cities need fit-for-purpose tools and approaches that are appropriate for their context and levels of investment in walking and cycling infrastructure.

1.3 Research overview

This first stage of this research sought to understand how latent demand for both walking and cycling is currently estimated in a range of New Zealand and overseas settings. It also assessed how well these methods incorporate data and research about existing travel behaviours and travel behaviour change, and their accuracy as determined by post-implementation count data (where possible). The second stage of this research employed the findings from stage 1 to create a decision tree, or framework, indicating approaches that could be adopted nationally in New Zealand for greater consistency in walking and cycling demand estimation. It also identified the need for, and initiated the development of, a walking and cycling demand case study database to aid the practice of forecasting walking and cycling demand in New Zealand.

1.3.1 Objectives

The main objectives of this research were as follows.

1. Review the range of factors known to be associated with walking and cycling travel behaviour and behaviour change in order to assess their incorporation in latent demand estimation methods.
2. Review the range of methodologies used over the last decade to estimate latent demand for walking and cycling, including an assessment of:
    a. the methods' advantages and disadvantages
    b. how well different methodologies incorporate the insights of research into transport customer behaviours
    c. their accuracy as determined by post-implementation count data.
3. Describe preferred approaches for different geographic scales and levels of network investment that could be adopted nationally in New Zealand for greater consistency in walking and cycling demand estimation.
4. Recommend a method for developing and testing estimates of latent demand.

1.3.2 Approach

The approach taken to address each of the research objectives is presented below.

Objective 1 sought to identify the range of factors associated with walking and cycling travel behaviour and behaviour change. This objective was addressed through a targeted review and summary of the literature.

Objective 2 is presented as a stocktake of the range of methodologies used over the last decade to estimate latent demand for walking and cycling. Methods for estimating latent demand were identified through a review of the literature and practice, as well as through a stakeholder and practitioner survey that was distributed within New Zealand and internationally. Follow-up interviews were employed with some survey respondents as required. The latent demand estimation methods were assessed based on the findings of this process, as well as the findings of the walking and cycling behavioural review from Objective 1.

Objective 3 resulted in the creation of a decision tree to guide practitioners towards the most fit-for-purpose methods to estimate latent demand for walking and cycling.

Objective 4 recommends a method for developing and testing estimates of latent demand. Based on the findings of objectives 1 and 2, the research identified several potential areas to develop and test estimates of latent demand, and these were presented to the research steering group. The steering group chose to proceed with the development of a Walking and Cycling Demand Case Study Database. This involved developing the database fields (presented in a spreadsheet format) and populating the database with an initial set of case studies.

1.4 Report structure

The report is structured as follows.

- **Chapter 2** presents the findings from the targeted review and summary of the literature into factors associated with walking and cycling travel behaviour and behaviour change.
- **Chapter 3** presents the findings of the primary data collected and review of the literature, which is a stocktake and assessment of the range of methodologies used over the last decade to estimate latent demand for walking and cycling.
- **Chapter 4** contains the decision tree to guide practitioners towards the most fit-for-purpose methods to estimate latent demand for walking and cycling.
- **Chapter 5** outlines the process used to develop the database fields and populate the database with an initial set of case studies.
- **Chapter 6** provides an overall summary of the research and its recommendations.

2 Review of the factors associated with walking and cycling

The purpose of this section is to review and discuss the range of factors associated with walking and cycling travel behaviour and behaviour change. A particular focus was understanding the similarities and differences in these factors for walking versus cycling, and the degree of consistency of association from place to place.

The findings from this review are summarised at the end of this section and are employed in Chapter 3 to support the assessment of walking and cycling latent demand estimation methods.

2.1 Introduction

Identifying factors that lead to behaviour change requires a whole-of-environment approach. Socioecological models of the determinants of wellbeing position individual behaviours as interacting within multiple contexts: geographical scales of households, neighbourhoods, settlements, regions and countries, as well as social, physical, cultural, economic, and political environments (Macintyre et al., 2002; Macmillan & Woodcock, 2017). How infrastructure changes affect individuals and communities will therefore be a reflection of many other factors, as well as the intended intervention itself.

There has been considerable effort made to determine the factors associated with changing walking and cycling behaviours. However, finding evidence for the effectiveness of interventions is challenging due to differences in study goals (and therefore design), the diversity of interventions, and the variable quality of studies (Stappers et al., 2018). For example, Stappers et al. (2018) found considerable variability in the quality of how studies managed bias. They observed a greater likelihood of reporting a significant change in outcomes among studies with a higher risk of bias, which could lead to an overestimation of effect if study results are taken at face value. Study designs that incorporate wider, more extensive infrastructural changes have also used more robust, complex survey designs with lower levels of bias risk. However, they argue that the more rigorous study design may underestimate intervention effectiveness compared to simpler interventions such as new cycling paths.

For the purposes of this review, we focus on factors at the individual and household level, and environmental factors, including the natural and built environments as well as specific physical active transport infrastructure and wider non-physical factors such as policies, so called ‘soft infrastructure’, and social norms that reflect the context within which the interventions take place (Stappers et al., 2018).

2.2 Individual and household factors

Who you are matters for how much you walk and cycle. Individual and household factors that have been identified as influencing walking and cycling behaviours include perceptions, sociodemographic characteristics, capability and competency, and trip purpose. These are now discussed in more detail.

2.2.1 Perceptions

Individual perceptions of modes influence active transport behaviours and experiences. Subjective perceptions include factors such as safety and aesthetics (Yang et al., 2019) as well as awareness or knowledge of infrastructure and its accessibility (Goodman et al., 2013; Heesch et al., 2015; Song et al., 2017). Perception of safety has been consistently identified as a strong factor that can encourage or discourage active modes (Butler, 2015; Cheyne et al., 2015; Kingham et al., 2011; Rossetti et al., 2018; Sullivan & O’Fallon, 2006). As Rossetti et al. (2018) state, this is likely because ‘users that feel cycling is safer tend to cycle more' (p. 252). Safety covers both threats from traffic and personal threats (eg, from rough surfaces or from crime due to poor lighting) (Sullivan & O'Fallon, 2006). While perceiving cycling to be safe from traffic has been associated with increased cycling, increased walking is associated with perceptions of personal safety, particularly among women. Safety factors that have been identified as a barrier to cycling include perceptions of driver attitudes and behaviours (Butler, 2015; Cheyne et al., 2015; Kingham et al., 2011).

Route choice is thought to reflect perceptions of safety, comfort and aesthetics (Park & Akar, 2019; Pritchard et al., 2019; Rossetti et al., 2018). For example, Rossetti et al. (2018) argue that objective safety measures do not always correspond with subjective measures as a way of explaining the decision to cycle and route choice. Cyclists are more likely to choose routes with higher comfort and aesthetic factors for recreational trips, and will also choose slightly longer routes for transport-related trips if they have more comfort and safety features such as greenery and fewer intersections (Park & Akar, 2019).

Perceptions and knowledge of where walking and cycling infrastructure is located is also related to usage (Goodman et al., 2013; Song et al., 2017). Not surprisingly, if residents do not know about a walk or cycle way, it is less likely their activity levels will be influenced by it. It also seems plausible that people may be less likely to know about walking and cycling improvements when they are located away from more primary travel routes.

2.2.2 Sociodemographic characteristics

There is mixed evidence for how sociodemographic factors influence walking and cycling behaviours. This may in part be due to many studies over-representing certain population groups and/or preferences for active transport. For example, Pritchard et al.'s (2019) study of route choice was sampled primarily from university students who commute by bike. The iConnect longitudinal study of a natural experiment in infrastructure intervention was skewed towards older, high socioeconomic status participants (Goodman et al., 2013). Nevertheless, there are some consistent findings. Rowangould and Tayarani (2016) found that the presence of bike paths was more important to women than men. In New Zealand, Sullivan and O'Fallon (2006) found that more men cycled regularly than women, and that more women than men had never learnt to ride. New Zealand research also shows that while cycling to work is not associated with any particular age group or level of income, walking to work is more common for people who live in lower-income areas (Shaw et al., 2015). On the other hand, Ton et al. (2019) did not find a gender effect in the Netherlands. Over and above whether people cycle or walk, what matters about walking and cycling seems to vary depending on who you are. Hebenstreit and Fellendorf (2018) found that different factors were more or less important by sociodemographic factors. For example, natural environment features such as green spaces and flat gradients were more important to those who were older and retirees than younger age groups and those in employment or looking for work.

Children's walking and cycling behaviours are heavily influenced by parental perceptions of safety (Carroll et al., 2015; Ferenchak & Marshall, 2019) and complex household car-based commuting trips (Quigg & Freeman, 2008), which can constrain children's opportunities to be more active. Hinckson et al. (2017) found in a New Zealand study that adolescent levels of physical activity were associated with aesthetic qualities such as greenery and attractive buildings, as well as physical characteristics such as residential density.

2.2.3 Capability and competency

Capability and competency matter for both cycling and walking, but perhaps to a greater extent for cycling. Capability, or experience, with walking and cycling matters for perceptions of safety and tolerance of lower levels of facilities. For example, Rowangould and Tayarani (2016) found that those who already cycle for utilitarian purposes would continue even if bike lanes and paths were not present. They concluded that cycling facilities were more important to less experienced cyclists because of perceptions of safety. As well as perceptions, having access to different forms of transport has been shown to correlate with transport modes. Having a bicycle in the household is related to increased cycling, while car ownership decreases the probability of walking and cycling (Ton et al., 2019). An implication of this is that children who grow up without access to a household (or other) bicycle may be less likely to become capable and competent at cycling, and this may interact with sociodemographic characteristics such as being from a household that can afford to purchase and maintain bicycles. Beyond the household capability, bike share programmes that provide relatively cheap access to bikes are thought to increase motivation to cycle (Kingham et al., 2011). Enjoyment is also related to capability and capacity factors. Factors that increased enjoyment included:

- competency with cycling, including feeling confident (Kingham et al., 2011)
- experience with cycling, which increases enthusiasm and confidence, even in less-than-friendly cycling environments (Butler, 2015)
- having the necessary gear (having a bike and helmet, suitable walking footwear, rainwear) (Kingham et al., 2011)
- having facilities at destinations such as bike storage and changing facilities (Kingham et al., 2011).

2.2.4 Trip purpose

The purpose of cycling or walking also matters for how much people walk and cycle. Living in a neighbourhood with a higher density of destinations has been associated with increased levels of physical activity (including walking and cycling for both utility and recreation) (Ivory et al., 2015; Witten et al., 2012), which is in part thought to be because trips can be made for purposes other than just exercise or recreation. On the other hand, the need to trip-chain and the need to transport heavy items and children have acted as barriers (Cheyne et al., 2015), which may interact with sociodemographic factors. For example, traditional family roles of women with children may have affected the gender balance in cycling. Cheyne et al. (2015) reported from a number of studies that greater distances to destinations were identified as a point of resistance to active modes. Kingham et al. (2011) found that the purpose of the trip was part of people’s mode decisions, such as commuting and recreational purposes, along with considerations such as convenience, speed, ‘presentability’ on arrival, and trip chaining all featuring in mode choice.

2.3 Environments

Individual walking and cycling practices occur within natural, built and social environmental contexts. They are influenced by, and in turn influence, what goes on around them at local, daily levels and in wider society and longer-term timeframes. For example, a decision to cycle to work one day might be affected by local weather conditions. It may also be influenced by what is considered ‘normal’ – for example, seeing others walk on clearly marked footpaths as part of an everyday commute.

2.3.1 Active transport infrastructure

The presence and quality of active transport infrastructure influences walking and cycling behaviours. This includes ‘hard’ infrastructure such as the streetscape (eg, footpaths, lighting), bicycle storage facilities, and separated bicycle paths (Butler, 2015), and it also includes ‘soft’ infrastructure such as bike share programmes (Fuller et al., 2013). As well as cycle- and walking-specific infrastructure, general street design that incorporates cycle friendly features is important; for example, traffic-calming measures such as speed humps that allow cyclists to easily ride through (Butler, 2015).

While shared paths provide separation from vehicle traffic, they do not necessarily increase cycling behaviours. Shared paths where cyclists and pedestrians are mixed have been shown to negatively affect cycling propensity (Deegan, 2015). Rowangould and Tayarani (2016) found that bike paths separated from traffic were a stronger motivator to cycle than bike lanes. However, having something was better than nothing; having no bike lane or path would lead to a reduction in cycling among less experienced cyclists.

2.3.2 Built environment

As noted above, trip purpose is an important influence on walking and cycling behaviours, and the built environment acts as a major source of ‘purpose’. The built environment can provide purposeful destinations such as libraries, playgrounds and shops (Ton et al., 2019; Witten et al., 2012) that motivate walking and cycling. Mixed land use helps provide a wider density of destinations within a shorter distance than less dense suburban form. Urban form factors such as higher densities of neighbourhood destinations and dwellings are associated with higher levels of walking (Witten et al., 2011, 2012), and they encourage cycling (Bauman et al., 2008).

2.3.3 Natural environment

Natural environment factors appear to play a key influencing role in walking and cycling because of how they affect the pleasantness of the trip and the effort required. Weather and topography are likely to be factors because they affect the pleasantness and comfort of the walking or cycling experience, as well as the amount of physical effort required, which Cheyne et al. (2015) identified as a barrier to cycling. Weather plays a significant role in mode choice across many studies and countries (Kingham et al., 2011; New Zealand Transport Agency, 2019). In line with previous studies in New Zealand and overseas, Cheyne et al. (2015, pp. 21–22) found that weather was cited as a main factor influencing whether or not survey respondents will walk (62.5%) or cycle (59.3%). In the Netherlands, weather seems to be a stronger factor for walking than cycling, but no relationship was shown between extreme weather and active transport modes (Ton et al., 2019), suggesting a persistence in behaviours through varying weather conditions.

The topography of walking and cycling routes also plays a role in mode choice (Kingham et al., 2011). Chen et al. (2018) showed that steepness is negatively associated with route choice for cycling. They found that the steeper the route, the less likely a route is to be chosen. Topography for walking has been less examined; in a review of accessibility measures, Vale et al. (2016) found only one example of topography being included in accessibility indices (Pearce et al., 2006), but the index was not designed to be a walkability index. It is not clear whether this is a methodological challenge yet to be overcome or whether slope steepness is not considered to be a significant factor for predicting walking behaviours. Given the variable topography in New Zealand towns and cities, capturing the presence of hills on walking routes may be needed.

The natural environment also influences behaviour through various route qualities. They include aesthetics (Cambra & Moura, 2020) and natural features such as waterways (blue space) and greenery (green space) (Chen et al., 2018). Gatrell (2013) referred to such route qualities as providing therapeutic mobilities that motivate activity in and through more pleasant and restorative environments (Ivory et al., 2015). Conversely, walking and cycling through unpleasant, hazardous places is thought to bring health dis-benefits (Gatrell, 2013), acting as a disincentive to be active in such places. Such qualities are likely to matter both for opportunities to engage in walking and cycling for recreation (are there pleasant places to walk?) and for enhancement (or otherwise) of utilitarian trips. Increasing the pleasantness and comfort could increase the utilisation of existing walking and cycling infrastructure.

2.3.4 Policy and society

Wider policy and societal factors affect walking and cycling behaviours. While not targeted at increasing active transport modes, the introduction of congestion charges to reduce traffic volumes and speeds has seen increases in cycling (Deegan, 2015). Traffic speed is consistently identified as a factor for cycling, both in terms of perceptions of safety (as discussed above) and observed behaviours. For example, Chen et al. (2018) found that routes with higher speed limits were less likely to be chosen by cyclists. Traffic and speed reductions in central London from congestion charging appear to be linked to increases in cycling, along with other infrastructure improvements and terrorism events that shifted people away from public transport to walking and cycling (Deegan, 2015).

Social norms around walking and cycling will both affect and be affected by behaviour and the wider physical environment, including provisions made for walking and cycling (Frohlich et al., 2001). That is, not seeing others cycle can reinforce beliefs that cycling is unsafe and decrease the likelihood that people will cycle, further reducing the chance of seeing cycling behaviours. Similarly, having visible active transport infrastructure can normalise active transport practices, increasing the demand for further facilities and fostering pro-cycling and walking practices. This recursive relationship between environments and behaviours is likely to underpin observations where cycling and walking begets more cycling and walking behaviour and demand for more facilities. Butler (2015) reported that comprehensive approaches to incentivising cycling were more likely to increase cycling levels; as well as infrastructure improvements, wider strategies such as restricting car use and pro-bike programmes were needed. Bauman et al. (2008) make the point that the higher the level of cycling, the safer it is, which may in part be due to drivers' increased familiarity with, and improved attitudes towards, cyclists and infrastructure.

2.4 Complexity

2.4.1 Interactions

Individual factors often interact. For example, the time taken for a walking or cycling trip was seen as a barrier only to those who do not walk or cycle for transport (Cheyne et al., 2015). Similarly, what might be seen as a barrier to some, such as hills, can be seen as a challenge to others (Kingham et al., 2011). Additionally, the relationships between factors and behaviours varied across countries and walking and cycling contexts, suggesting social and cultural norms are likely to be part of the system. While 'safety' is a consistent factor, for example, how it plays out may differ depending on the maturity of walking and cycling infrastructure and behaviour.

2.4.2 A whole-of-environment approach

Walking and cycling infrastructure on its own is not enough, particularly if it is not connected to a wider active transport network (Goodman et al., 2013; Stappers et al., 2018). Additionally, the choice to walk or cycle for a trip with be affected by the relative utility (or generalised costs) of other transport options available, such as driving or public transport. Factors that may affect the relative utility of transport options include monetary costs (such as for fuel or public transport), congestion, travel time and reliability. In particular, the availability of car parking has been shown to offset the effect of increased provisions for walking and cycling on mode choice (Hamre et al., 2014).

The overall quality of the built and natural environment helps to make active transport modes possible and desired. Urban form is needed to provide meaningful destinations that encourage utilitarian trips. General street design can support more specific and specialised infrastructure by ensuring that walking and cycling around neighbourhood streets is safe and efficient.

Urban form sets the scene for how easy it is to walk and cycle as well as providing purpose for trips. Factors such as street connectivity and dwelling density affect the distance travelled, while streetscapes capture how possible and pleasant it is to walk on pedestrian-appropriate surfaces. Having local destinations provided in medium- and high-density urban form can provide a reason for local trips to be undertaken on foot or by bike, rather than by private car. Combining ease and purpose can be key to shifting transport to more active modes. An example of this is Wellington city, which has a relatively compact urban form and a relatively high mode share of walk trips compared to other New Zealand cities.

2.4.3 Walking and cycling as separate but connected modes

Ton et al. (2019) found that walking and cycling have different determinants and that these determinants matter to different extents. This suggests that walking and cycling modes must be considered separately rather than being grouped together as a homogenous ‘active transport’ mode. On the other hand, active and public transport modes appear to support each other (although perhaps in different ways). Heesch et al. (2015) found that linking nodes allowed longer journeys; for example, being able to cycle to a ferry or rail station where bikes can be loaded for the commute to the central business district. New Zealand research has also shown that better integration between cycling and public transport would increase both cycling and public transport levels of use (Ensor et al., 2010).

2.4.4 Between-country differences: active transport maturity

The discussion above has identified a range of factors shown to influence walking and cycling behaviours. The extent to which they matter appears to vary between countries, suggesting wider socio-cultural factors around active transport are likely to be at play. In the Netherlands, for example, factors such as weather, seasonality, trip chaining, gender, and car ownership play much less of a role (Ton et al., 2019). Ton et al. (2019) suggest this is because in the Netherlands, cycling and walking behaviours are relatively universal and supportive infrastructure is comprehensive, meaning both of these active transport modes are normalised. While factors such as cycle ownership are related to cycling behaviours in other countries, no such relationship was seen in the Netherlands, perhaps showing a degree of active transport behavioural and infrastructural ‘saturation’. The maturity of walking and cycling within a country may also help to explain why shared pathways are more of an incentive in some countries than in others. Urban form may also potentially moderate the ‘maturity’ factor. For example, New Zealand has plenty of footpaths but fewer destinations in suburban than urban areas (Witten et al., 2011).

2.5 Behavioural factors discussion

This review presented a discussion of the range of factors associated with walking and cycling travel behaviour and behaviour change. It has shown that while the determinants of walking and cycling may overlap in some instances, they diverge in others, and also that the strength of association varies between modes (for further detail see Ton et al., 2019). The implication of this is that methods to assess latent demand for walking and cycling must consider them separately in order to adequality represent them. This review has also shown that the factors influencing walking and cycling behaviour are dynamic, in that they can vary substantially from place to place, perhaps indicated by active transport maturity. The implication of this for walking and cycling latent demand estimation methods is that the transferability of data, factor associations, and parameters between places must be assessed carefully.

The findings from this review are further employed in Chapter 3 to support the assessment of walking and cycling latent demand estimation methods.

3 Stocktake and assessment of walking and cycling latent demand estimation methods

3.1 Introduction

The objective of this chapter is to review the range of methods used over the past decade to estimate latent demand for walking and cycling, including an assessment of:

- the methods' advantages and disadvantages
- how well different methodologies incorporate the insights of research into transport customer behaviours (from Chapter 2)
- their accuracy as determined by post-implementation count data.

3.1.1 Methodology

Methods for estimating latent demand were identified through a review of the literature and published practice, as well as through a stakeholder and practitioner survey that was distributed within New Zealand and internationally. Follow-up semi-structured interviews were employed with some survey respondents to gather additional information as required. The latent demand estimation methods discovered were categorised and assessed based on the findings of this process, as well as the findings of the walking and cycling behavioural review from Objective 1.

For each method, we attempted to gather the following information (where available).

- Background
- Purpose
- Development and structural components (modes, variables, relationships, assumptions, data)
- Application and use (projects, before/after count data (accuracy), validation)
- Assessment: strengths and weaknesses, constraints

The survey was distributed using a 'snowball' sampling approach to 'crowdsource' methods and case studies from a range of New Zealand and overseas practitioners and academics, as many are not documented or are at least not publicly available. The survey was sent to an initial list of contacts identified during the steering group meetings, from the peer reviewers, by the research team, and also through a question in the survey. The survey also sought reflections of the current state of practice, as well as the need and potential for improvement. The complete survey is presented in Appendix A.

3.1.2 Sample

The survey generated 31 complete responses. Additionally, five respondents chose to email feedback to the research team rather than take the survey. Nine follow-up interviews were conducted, representing a range of stakeholder and practitioner types, both over the phone and in person.

The survey respondents tended to be practitioners or researchers who had been involved in the development or application of latent demand forecasting methods, with more complex modelling approaches being highly represented in the sample. Given that, anecdotally at least, more complex modelling approaches do not tend to be widely used in New Zealand practice, it appears the survey may have been more engaging to practitioners who had substantial experience and involvement in the field rather than those who had used more simple, pragmatic approaches. However, enough responses were collected from a range of perspectives and experience levels, and when combined with the findings from the literature, it is the authors' opinion that the stocktake has captured a wide range of methods currently in use. To summarise, those in the survey sample were:

- mostly method developers, with some users and general stakeholders
- more representative of complex methods, such as models
- a mix of academics (less) and practitioners (more)
- based in New Zealand (more) and overseas (less).

3.1.3 Presentation

The findings of the literature review and primary data collection (survey and interviews) are presented together, as both were used to collect the body of information that forms the stocktake of latent demand estimation methods, and to inform their assessment. Published information is presented using the conventional referencing format. Information gathered through primary data collection is identified by feedback route (eg, survey or interview) and the respondent's role (when known): method developer, method user, or general stakeholder (when the person is not directly associated with any particular method, but latent demand is relevant to their work).

3.2 Findings

The past decade has seen substantial progress made to develop the range and quality of methods used to forecast latent demand for walking and cycling. It has also seen efforts being made to better incorporate insights from research into walking and cycling behaviour and behaviour change. As expected, this research found that methods to forecast demand for cycling were far more abundant and tended to be more advanced than those for walking. Additionally, the information available about the various methods, their application, and their evaluation is highly variable and inconsistent. Some methods are well documented, while others have very little information in the public realm, which is reflected in what is able to be presented in this stocktake. It also poses challenges to making a thorough assessment and comparison of many of the methods.

Despite the recent progress that has been made, there was a general level of caution among respondents as to the reliability of walking and cycling forecasts, with some commenting that transportation forecasts in general are not seen as highly credible (for any mode). This finding supports a recent claim by Jongeneel (2017, Abstract), which describes methods to forecast active transport demand as being 'in their infancy both in New Zealand and internationally'.

This does not mean that latent demand estimation methods and their forecasts have no place; they can be incredibly useful in aiding transport planning and investment decision making. But an overarching theme from respondents is that they must be used carefully, with acknowledgement of their relative importance, of both what they do and what they do not consider, and of what assumptions have been made in forming them.

Key resources identified by the review of the literature that may be of value to practitioners working in the walking and cycling demand forecasting field are:

- a United States guidebook titled *Estimating Bicycling and Walking for Planning and Project Development* by Kuzmyak et al. (2014)

- a United States walking and cycling modelling evaluation of practice and the state of the art titled *Evaluation of Walk and Bicycle Demand Modeling Practice* by Bradley et al. (2019)
- the United Kingdom transport analysis guidance *TAG Unit A5.1: Active Mode Appraisal* issued by the Department for Transport (2018). (Chapter 2 of this guidance document provides useful guidance and considerations for pragmatic approaches to active modes demand forecasting.)

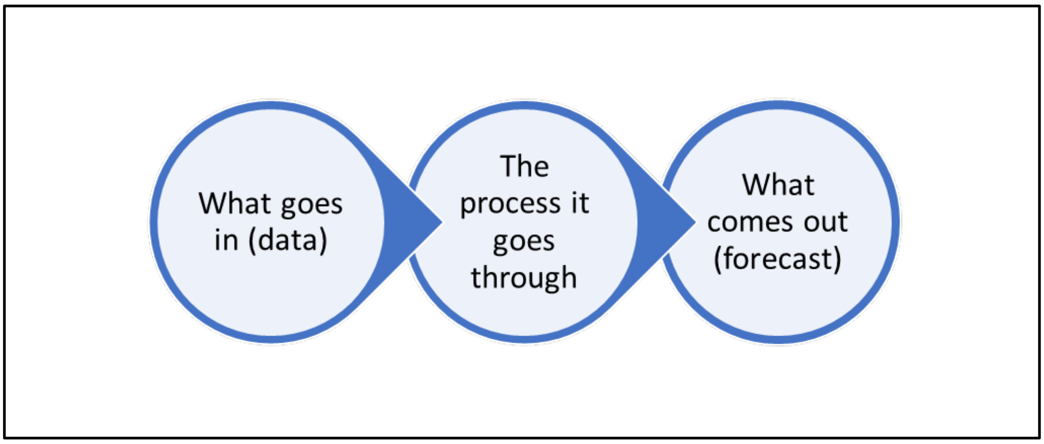
3.2.1 Conceptualising latent demand estimation methods

One of the first findings of the stocktake was that categorising and understanding the various latent demand estimation methods can be confusing due to inconsistent terminology employed to categorise and describe them. This inconsistency was also noticed by Lovelace et al. (2017, p. 507), who point out that:

> *the work can be classified in a number of ways, including by the main mechanism of the tool (e.g., facility demand or mode choice models), the format of its outputs (e.g., spreadsheet results, GIS-based map or on-line, interactive map) or by the main level of the input data used.*

Using Lovelace et al.'s (2017) classification framework, this research has sought to conceptualise the various latent demand estimation methods by understanding what goes in, what process it goes through, and what comes out (see Figure 3.1).

Figure 3.1 The conceptual framework used to understand and assess the various latent demand estimation methods (adapted from Lovelace et al., 2017)



For example, **what goes in** may include one or combinations of:

- data collected about people, what people do (eg, counts, travel surveys, Global Positioning System (GPS) data), or what they say they prefer or would do (eg, stated preference surveys)
- data collected about places and transport systems
- aggregate or disaggregate data
- local data or knowledge, or data and knowledge from elsewhere
- representations and forecasts taken from other models, such as land use, employment, or general transport forecasts
- interpretations or assumptions to overcome data limitations.

The process the data goes through may include one or combinations of:

- a model – that is, some form of structured way of representing something to make it easier to understand, such as:
  - a mathematical model, or sequence of models
  - a traditional transport modelling type process or software
  - a conceptual framework
- a process or procedure of assessment
- a geographic information system (GIS)
- interpretations or assumptions around data and knowledge (either to overcome limitations or to attempt to apply them to practice).

What comes out can include forecasts for different various spatial scales (eg, places or networks, routes, fine or coarse), and for various timeframes (such as a snap-shot at some future point in time, a step change due to infrastructure and/or a change in overall trends over time).

3.2.2 Latent demand estimation method categories

Based on this conceptual framework, the walking and cycling latent demand estimation methods identified and documented in this research have been grouped into the following categories.

- **Pragmatic approaches** (where what goes in, the process it goes through, and what comes out are chosen considering what is at hand, what is needed, and what works for the given situation), including:
  - informed expert estimation:
    - as the basis of the forecast
    - to rationally adjust a forecast from another method, or
    - to make assumptions about components of a method or model (data, variables, and relationships)
  - comparison approaches
  - sketch planning
- **Demand typologies** (where ‘what comes out’ is a categorisation of a population to identify groups with latent demand for walking and cycling)
- **Stated preference based** (where ‘what goes in’ is based on stated preference data or what people say they prefer or would do)
- **Revealed preference based** (where ‘what goes in’ is based on data representing what people are doing or have done)
- **Traditional transport models** (where conventional transport modelling processes are adapted to improve suitability for walking and cycling)
- **Geospatial assessments** (where data is processed and/or presented in a GIS)

The use of **accessibility approaches** and **system dynamics models** were also raised by some participants. These categories are further discussed, and examples are provided, in the next section.

3.3 Stocktake

3.3.1 Pragmatic approaches

The first set of methods are a range of pragmatic approaches for estimating latent demand for walking and cycling. For the purposes of this work, a pragmatic approach is defined as one that asks 'What works?' and includes methods that are less structured, ad-hoc, or relatively generic in their approach.

These approaches tend to be used either when more structured or locally specific methods or models are not available, or when they are seen as unsuitable or insufficient for the given purpose (for example, if the project is beyond the parameters of the usual local method or model). In these instances, practitioners tend to ask: What is needed here, what should be considered, what data is available, and what works for the given purpose? As such, the approaches used tend to be ad-hoc in nature, captured aptly by one survey respondent who commented:

> *I am not aware of robust methods, so you have to use whatever you can get. (Survey, method developer and stakeholder)*

Another interview participant also highlighted this point, stating:

> *Latent demand forecasts for walking and cycling are ad-hoc in [our jurisdiction] too. It's all about: Who do you need to convince and what do they need in order to be convinced?*

It is clear from these statements and other feedback from stakeholders in the survey that currently there is very little consistency in the practice of walking and cycling demand forecasting in New Zealand as well as in some overseas locations. The latter comment also speaks to the political nature of demand forecasting, in that sometimes the approach chosen is simply one that will 'tick the boxes' of the policy and funding requirements of the time.

Pragmatic approaches to latent demand forecasting may include the use of one, or any combination of, the following methods:

- informed expert estimation
- sketch planning
- comparison approach.

These methods are now presented in more detail and evaluated, with case study examples provided.

3.3.1.1 Informed expert estimation

It is apparent from this research that producing latent demand forecasts requires collecting and interpreting data that attempts to represent aspects of past, present, or hypothetical future situated human behaviour or preference, and then to interpret the observed patterns to try to predict what may happen given some expected change in the future. The implication of this is that, to varying extents, all latent demand forecasting methods include expert judgement; they all make informed assumptions, sometimes many compounding assumptions, and thus all have a level of subjectivity. This inherent subjectivity involved in producing walking and cycling, as well as other transport demand forecasts, is often not explicitly identified or discussed.

Based on the literature review and primary data collection, this research has identified that informed expert estimation contributes to walking and cycling latent demand forecasting in three main ways:

- as the basis of a forecast

- as choices and assumptions about components of a method or model (such as data, variables, and relationships), and/or
- to rationally adjust a forecast from another method.

Each of these three approaches are now presented in more detail.

Informed expert estimation: As the basis of a forecast

When used as the basis of a forecast, informed expert estimations are ultimately subjective estimates, or 'logical assessments' as one respondent described them, of latent demand. They tend to be formed based on any relevant information and data that is available or readily collected, taken with consideration to specific local characteristics and needs, and then combined with professional experience and judgement. This professional experience and judgement can sometimes include quite substantial local knowledge and a history of making professional observations, as well as a track record of relevant walking and cycling project experience. As such, it is entirely plausible that some professionals may be able to produce reasonably accurate and well considered forecasts. However, demonstrating the reliability of professional judgement as the basis of a forecast can be problematic, and there is also clearly room for subjectivity, bias or an agenda to influence the result (as there is for many transport forecasts, to varying extents, as already discussed).

Types of information that survey respondents stated that they had considered to form a subjective estimate of latent demand for walking and cycling included:

- past, recent/present and projected local travel behaviour and trends, taken from:
  - count data
  - household travel survey data
  - census journey-to-work mode share data
  - GPS travel data (such as from Strava)
  - output from local general transport models (such as future projections)
  - output from other models and research, from New Zealand and overseas
- local urban and transport characteristics, including:
  - places of trip generation and attraction (such as schools or residential catchment population)
  - network connectivity
- comparisons with other similar projects or facilities, either local or elsewhere.

Survey feedback identified two specific cases where informed expert estimation has been used as the basis of latent demand forecasts on projects, although it seems probable that our study has only identified a small number of cases. Neither of the two projects had evaluated the accuracy of the forecasts using post-implementation count data (this was regularly identified as an issue by the survey and interview respondents for all methods). Feedback regarding the use of informed expert estimation as the basis of the latent demand forecasts from these two cases was that it was low cost, reasonably quick, and required a moderate amount of data combined with a high level of expertise. It was also seen as a method that could be readily applied to other places.

Informed expert estimation: As choices and assumptions about components of a method or model

All of the latent demand estimation methods identified demonstrated a degree of informed expert estimation or judgement. This begins at the point of deciding (or being limited by) what data to use, from where, and about whom. It then includes decisions about how to analyse, represent, interpret and apply that data to produce a forecast. This may include decisions about how to annualise count data, what sites to collect count data for, who to survey and how, and what questions to ask. It may also include choosing what trip types to assess (eg, which travel modes and what journey times and purposes). For example, historically there has been a significant emphasis on prioritising the collection and modelling of data for vehicle-based travel to work at peak times, at the exclusion of other modes, trip types and travel times. When analysing or modelling data, the practitioner then has to make choices and assumptions regarding which variables are important to consider, as well as how to represent the relationships between variables (where some may be based on the regression relationships of local data, some may be based on old data or data from overseas, and some may be assumed or estimated). We can see from this discussion that there are many stages and ways for subjective choices and assumptions to influence the components of a demand forecasting method, and thus also be reflected in the resulting forecast.

Each step of this process includes a judgement on the part of the decision makers: What matters here? What we choose to measure can reflect what we value, as well as what may be easier to measure. The implication of this is that it is very important that forecasts are produced within a context of transparency around what they can and cannot do: what they take into account, what assumptions they make, and their strengths and limitations. Informed expert estimation about components of a method can influence:

- what goes in, including:
  - what to count and where
  - how to interpret data (eg, choosing how to annualise count data)
  - whom to survey and what questions to ask (eg, for what trip types, whether to count all trip legs or simply the primary origin and destination)
- the process it goes through, including:
  - what variables are important to consider/model
  - what trip types matter (eg, peak travel, journey to work only) (may bias against those who do not work)
  - how to represent the relationships between variables (some may be based on local data, some may be based on old data from overseas, some may be guessed)
- what comes out, including:
  - how to interpret what the forecast means (such as its level of accuracy and application to investments)
  - judging the forecast inaccurate and modifying it based on reasoning.

Informed expert estimation: To rationally adjust a forecast from another method

This approach involves the modification, or complementing, of output from any of the other methods. This research identified cases where the forecasts from established latent demand estimation methods were seen to not fully account for circumstances that may affect future levels of use for a proposed project. Such circumstances include, for example, a project that is anticipated to be an attraction in its own right for both local people and tourists. Examples of this were identified by survey respondents where the output from a transport model was adjusted using informed expert estimation in order to take into account relevant factors that they felt the model did not address.

3.3.1.2 Sketch plan methods

Sketch plan latent demand forecasting methods are relatively coarse and generic formulas or factoring. Sketch plan methods are generally seen as being easy, fast and cheap to do, but also tended to be seen by respondents as having low accuracy. For this reason, survey and interview respondents who said they had employed sketch plan methods tended to use them with caution, and also modified them based on either informed expert estimation approaches or through the use of comparison case studies (discussed in the next section). The two main sketch plan methods in New Zealand are the *Economic Evaluation Manual* (EEM) simplified procedure for walking and cycling facilities (SP11) and the Land Transport New Zealand (LTNZ) Research Report 340 methods, which are now discussed.

EEM SP11

The New Zealand Transport Agency's (2018) *Economic Evaluation Manual* prescribes a sketch plan method to forecast demand for cycling facility improvements. The data that this method is based on was derived from a model developed for two cities in the United States, for on-road urban cycle facilities (Wilke & Fowler, 2015). Spreadsheet SP11-7 is provided for estimating new cycling volumes. However, no worksheets are provided to estimate walking volumes for improved walking facilities. The cycling method forecasts the total new daily cycle commuters, as well as total new daily other cyclists.

Variables considered include:

- existing cyclist commuter mode share for the local area (based on census data)
- resident population living within three 'buffer zones' within set distances of the proposed facility (deduced using GIS).

A multiplier is provided for the likelihood of a new cyclist within each buffer zone, and total existing daily cyclists and total new daily cyclists are then produced.

The method's main weaknesses are that it:

- relies on an adjacent resident population, so it is not suitable in some circumstances (such as for bridges, or routes with no or low adjacent population, and also for places with a higher than usual population density like city centres)
- does not readily account for the effect of the type of improvement or level of service on demand
- cannot easily compare two routes serving the same population buffer zone
- does not provide for walking.

One research participant also pointed out during an interview that methods using adjacent residential population buffers as a main input for demand forecasts can be seen as unfair for some types of places, such as regional towns, that cannot justify walking and cycling improvements based on measures of their population density.

LTNZ Research Report 340 methods

LTNZ Research Report 340 produced cycling latent demand estimation sketch plan methods for both on-road and off-road facilities, based on 10 New Zealand case studies (McDonald et al., 2007). These methods were developed with the intention of having a nationally consistent approach to cycle facility demand forecasts that use readily available data and are simple to apply.

The on-road method is used to forecast the effect of a new cycling facility on an existing road using a step-change function. New cycle trips are calculated as a 20% increase on the existing average annual daily cycle flow. Data required includes existing cycling volumes and a census journey-to-work mode share growth rate.

The off-road method is used to forecast the effect of a new cycling facility parallel to an existing road. It uses the average annual daily cycle and traffic flow of the adjacent road, census data on journey-to-work cycle mode share, and the census journey-to-work mode share growth rate. The off-road method also increases the background cycle mode share growth rate by 14% of the current rate to account for the ongoing appeal of off-road facilities.

One strength of these methods is that they distinguish between the effect of on-road and off-road cycle facilities on demand. Some weaknesses of these methods are that they:

- do not account for walking
- rely on existing cycling levels of use, so may not be suitable where cycle numbers are very low or non-existent
- are based on a small number of case studies (Southey-Jensen et al., 2015).

Jongeneel (2017) compared EEM SP11 and LTNZ Research Report 340 sketch plan demand forecasts for routes in Auckland with forecasts from the Auckland Cycling Model (presented in the transport modelling section of this stocktake). The results of this comparison are shown in Table 3.1.

Table 3.1 Comparison of three demand forecasting methods (Source: Jongeneel, 2017, p. 12)

Route	Observed Cyclists (2016)	2016 Auckland Cycle Model		Research Report 340		EEM Simplified Procedures 11	
		Cyclists	Error	Cyclists	Error	Cyclists	Error
Beach Road	343	263	-23%	392	+14%	1,158	+237%
Carlton Gore Road	317	410	+29%	423	+33%	1,067	+237%
Grafton Gully	344	373	+8%	465	+35%	1,660	+383%
Nelson Street	340	373	+10%	64	-81%	1,535	+352%
Lightpath	375	351	-6%	248	-34%	1,594	+325%
Quay Street	715	761	-6%	628	-12%	956	+34%
Average Error			**±14%**		**±35%**		**±261%**

As seen in Table 3.1, the EEM SP11 method consistently gave very high demand forecasts due to a dense adjacent residential population for most of the routes. The LTNZ Research Report 340 methods had a much smaller average error range; however, the accuracy range of the forecasts fluctuated substantially, reflecting the varying levels of use of the route by cyclists before the improvements were made.

3.3.1.3 Comparison approaches

Comparison approaches to latent demand forecasting for walking and cycling involve looking at walking and cycling levels, or changes in levels due to some interventions, in certain places, and using this information to estimate latent demand in other similar types of places. Research respondents discussed using comparison approaches primarily to quality-check the forecasts produced by sketch plan methods, and also to justify the modification of forecasts from other methods as needed.

In a recent review of active modes demand estimation methods, Khoo and Weerappulige (2020) advise that for New Zealand projects, active mode models should be used to forecast walking and cycling demand when they are available and suitable. In the absence of this, when a suitable transport model or journey-to-work data is available, they recommend this be used to develop an active mode trip matrix and estimate trends over time, and that the effect of the project on demand uptake should be estimated through use of a comparison approach. They advise that in other instances, if the EEM SP11 method is not suitable, comparison cases should be used to estimate demand for a new facility. They present three formulas to use depending on the data available, shown in Figure 3.2.

Figure 3.2 Comparison formulas proposed to estimate cycle demand (adapted from Khoo and Weerappulige, 2020, p. 48)

- Cycle count of new facility = (Population of CAU of new facility/Population of CAU of existing facility) × Cycle count of existing facility
- Cycle count of new facility = (Bicycle work trips of CAU of new facility/Bicycle work trips of CAU of existing facility) × Cycle count of existing facility
- After cycle count of new facility = (Before cycle count of new facility/Before cycle count of existing facility) × After cycle count of existing facility

CAU = census area unit

The United Kingdom Department for Transport’s (2018) *TAG Unit A5.1: Active Mode Appraisal* also promotes the use of comparison studies as ‘the least complex and costly’ way to estimate demand for walking and cycling. It emphasises being aware of instances where the comparative case study may have had external influence from local factors that may not apply to the new location.

Many of the research respondents were generally interested in the wider use of comparison approaches for latent demand forecasting; however, they said a major barrier was the very limited access within New Zealand to good quality case study data with accurate before and after counts. Importantly, a lack of data was also identified as a major barrier to quality walking and cycling demand forecasting in New Zealand in general and was the most commonly requested area for improvement.

The case study below from Queensland shows the development of a walking and cycling project demand case study database, which is used to understand demand and inform demand estimates for proposed local projects.

Queensland’s walking and cycling case study database

One survey and interview respondent (method developer) discussed the approach taken in Queensland, Australia.[1] Here the local authority collects before and after data for walking and cycling projects so they can be evaluated and also in order to develop a database of case studies to use to forecast demand for future projects. This respondent pointed out that site selection is important for ensuring the reliability of counts, and that it can be useful to take counts at several points along the corridor. They also found post-completion intercept surveys of users to be valuable, providing trip information such as distance, origin and destination. This can also be an opportunity to ask users about their past walking and cycling behaviour and any recent

[1] by the Department of Transport and Main Roads

behaviour change. This approach of using intercept surveys on recently completed cycling infrastructure has also been used in Christchurch (Ferigo, 2017).

The creation of a local demand case study database was rated by this research respondent as being reasonably resource intensive in terms of cost, time, data, expertise and technology – primarily due to data collection. It was also rated as being accurate and fit-for-purpose, but as having low transferability, indicating the perception that the demand data was specific to the characteristics of the local area and may not be suitable to infer demand in other places.

3.3.2 Demand typology methods

People with a latent demand for walking and cycling are perhaps the ones who are more likely to increase their walking and/or cycling due to investments that support these modes. It is reasonably straightforward to identify those who have an existing demand for walking and cycling, as it is those people who are currently engaging in the behaviour (although these people may also have a level of latent demand). In order to assess the preferences of people with a latent demand, as well as the scale of latent demand for walking and cycling, it is necessary to identify those sub-groups of people. This is where demand typology methods can be useful. Demand typology methods allow us to assess the proportions of a population with particular demand characteristics, as well as to qualitatively assess the preferences of those with latent demand.

Several methods are in use to group or categorise populations based on their walking and cycling demand characteristics. On their own, these do not directly quantify latent demand for any specific walking and cycling facilities, but they can be useful in understanding the level and qualities of (latent) demand, as well as identifying the spatial distribution and preferences of those with higher potential to change their behaviour. They can also be used on a semi-regular basis to track change in latent demand within a population over time, which can be a useful way to assess the non-behavioural impacts of walking and cycling promotion policies and activities (eg, an increase in the number of people who would consider it).

The demand typology methods are presented below. Most have a cycling focus, with the exception of the Stages of Change and the Classification of Londoners approaches, which have also been applied to walking. However, all of the examples provided could be modified and applied to assess walking demand.

3.3.2.1 The ‘Four Types of Cyclists’

The ‘Four Types of Cyclists’ classification was initially developed in 2005 based on ‘professional knowledge and experience in a field where data is woefully inadequate’ (Geller, 2006, p. 9). It identified four general categories of transportation cyclists and their needs in Portland, Oregon, in the United States. The categories were formed based on an assessment of people’s bicycle use and attitudes to cycling. The groups are:

- **The Strong and the Fearless:** those who are likely to cycle almost anywhere
- **The Enthused and the Confident:** those who are comfortable sharing the road with vehicles but prefer dedicated cycling facilities
- **The Interested but Concerned:** those who are curious about cycling and enjoy riding a bike, but are concerned about safety risks from vehicles and so don’t usually ride regularly and would likely ride more often if they felt safer
- **No Way No How:** those who have no current interest in cycling.

More information on the application of the Four Types of Cyclists typology can be found in publications such as Dill and McNeil (2013, 2016), Geller (2006), and also in New Zealand by McClure (2016) where the typology was applied to Christchurch.

3.3.2.2 The Transtheoretical Model of Intentional Behaviour Change: The Stages of Change

The Transtheoretical Model (TTM) of Intentional Behaviour Change was developed between 1984 and 1994 (DiClemente, 2007). It distinguishes five key psychological and behavioural phases in the process of behaviour change and calls these the Stages of Change (DiClemente, 2007). The TTM identifies how prepared and willing individuals are to change a particular behaviour so that interventions can be appropriately targeted. It has been used to investigate active transport behaviour, both overseas and in New Zealand. In active transport research, it has been used to explore potential cyclists' underlying motivations and readiness for behaviour change.

A number of studies have used the TTM to investigate the potential for active transport behaviour change in the UK (eg, Davies et al., 1997; Davies et al., 2001; Gatersleben & Appleton, 2007; Mutrie et al., 2002), Australia (eg, Shannon et al., 2006) and in New Zealand (Sullivan & O'Fallon, 2006). Sullivan and O'Fallon's (2006) study was funded by LTNZ and was based on a large nationwide questionnaire. It included questions to establish respondents' Stages of Change (giving representative regional and national proportions), as well as their motivations, and perceived barriers and benefits of transport cycling and walking (Sullivan & O'Fallon, 2006). In 2012, the Greater Wellington Regional Council employed the Stages of Change categories to assess the potential for, and perceptions of, transport cycling in the region (Greater Wellington Regional Council, 2012). Beetham (2014) also used the Stages of Change to explore the characteristics of latent demand across the segments for cycling and safer cycling routes in Wellington.

3.3.2.3 New Zealand cycling preferences and market segmentation

Wooliscroft and Ganglmair-Wooliscroft (2014) employed a discrete choice modelling method (conjoint analysis) to assess attitudes and stated potential cycling behaviour using a national survey of a large and closely representative sample of adult New Zealanders. Conjoint analysis is a stated preference survey method that enables evaluation of the utility of various attributes presented within a hypothetical choice, such as transportation choices.

The study found that 10.5% of New Zealanders would not consider cycling in any of the choice scenarios, while 0.8% would always cycle. The remaining 88.7% of respondents stated propensity to cycle was influenced by the attributes within the choice model. These attributes included petrol price, presence of cycle lanes, presence of cycle facilities at the end of the trip, and perception of driver attitude towards cyclists. This study found that the main barrier to the uptake of cycling for potential cyclists was the perception of aggressive driver attitudes. The study also found a high level of support for increased public spending on cycling facilities, with the average preference of 21.3% of the transport budget being spent on such facilities, when actual spending was 0.6% for both cycling and walking at that time.

3.3.2.4 Wellington cycling preferences and market segmentation

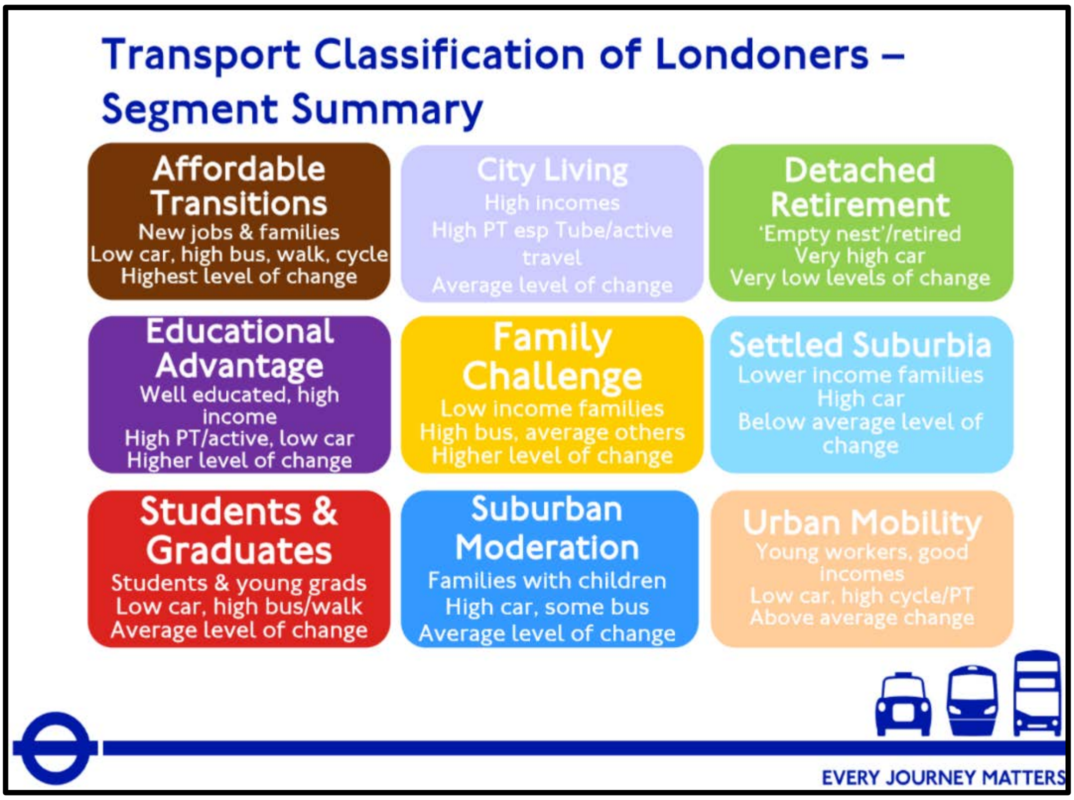
Another study[2] grouped Wellington residents into market segments based on their responses to a cycling stated preference survey (Pettit & Dodge, 2014). Responses were analysed using latent class multinomial logit modelling, which identified six underlying cycling types in Wellington city, based on their shared cycling and route preferences. These groups are: Non-Cyclists, Hesitant Cyclists, Recreational Cyclists, Likely Cyclists, Safe Cyclists, and Dedicated Cyclists. Cycling and cycle route preferences, as well as demographic characteristics, varied across the six groups.

[2] by the Wellington City Council and New Zealand Centre for Sustainable Cities

3.3.2.5 Transport Classification of Londoners

The Transport Classification of Londoners[3] is a 'multi-modal customer segmentation tool' that groups London residents into nine categories based on their travel behaviour, transport preferences and attitudes, propensity for travel behaviour change, and socio-demographic characteristics (Chinnock & Blair, 2017). Information sources for the classification tool included census data, the annual London Travel Demand Survey, and a bespoke travel segmentation survey. The nine categories developed to reflect the London population are shown in Figure 3.3 below. The spatial distribution of the nine groups is mapped for the greater London area, which aids transport policy and investment decision making by focusing investment in locations where there is higher potential for uptake.

Figure 3.3 The Transport Classification of Londoners segments (Source: Chinnock & Blair, 2017, p. 7)



This section has presented a range of methods useful to assess walking and cycling demand typologies across a population. Demand typology methods can be used to assess the proportions of a population with particular demand characteristics, as well as to qualitatively assess the preferences of those with latent demand. This can be useful to support the targeting of investments to match the locations where the highest level of latent demand is, or to explore the drivers behind spatial variations in latent demand (such as inequities) and to provide insight to ensure investment design is fit for purpose. They can also be useful to track how walking and cycling programmes are performing over time.

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[3] by Transport for London

3.3.3 Stated preference

Some walking and cycling latent demand forecasting methods employ stated preference data and techniques. This section presents methods that are primarily based on stated preference data and techniques; however, other methods also incorporate stated preference components into their demand assessments (eg, Wardman et al. (2007) combined stated and revealed preference data).

Stated preference methods are particularly useful for testing perceptions, and the potential behavioural response, of those people with latent demand for walking and cycling, or to infrastructure that is substantially different or new and therefore there is no reliable data on the behavioural response it may generate (Hensher, 1994). Stated preference data is typically collected through a survey that involves individuals responding to questions by indicating a hypothetical choice, or by indicating a hypothetical behavioural response or preference to a proposed situation (Brown, 2003; Kroes & Sheldon, 1988).

Stated preference methods can be seen as being unreliable and prone to bias, with the risk of people ‘responding with their agenda rather than their behaviour’ (Hood et al., 2011, p. 10), and as such these authors argue that stated preference data should be verified using revealed preference data. It is also important that stated preference studies attempt to reduce bias through the use of a representative sample and by applying best practice to study design, as appropriate for the method in use. Stated preference methods, and indeed all methods, should also explicitly point out the limitations of their findings. A range of stated preference methods are now presented.

3.3.3.1 Wellington Cycle Demand Model

Background

The Wellington Cycle Demand Model[4] (WCDM) was developed in 2014 and is currently undergoing a revision (interview feedback, method developers). The development and validation discussion of the initial model is discussed in Pettit and Dodge (2014, pp. 30–37) and is also briefly outlined here.

Method overview

The WCDM is spreadsheet-based and was developed from discrete choice survey data from a survey of Wellington City Council’s panel of residents in 2014. Discrete choice models attempt to predict individual travel choices based on the trip characteristics (Jones et al., 2010) and can be based on stated or revealed preference data. The WCDM also employs census data and automatic and manual cycle count data (where the automatic counts are used to annualise the manual counts) (interview feedback, method developers).

The discrete choice component of the model is built from the stated preference survey data, which measured hypothetical choice trade-offs between, and preferences for, travel time, cycle facility type (mid-block), presence of adjacent car parking, presence of adjacent traffic, and slope. The coefficients for each of these factors were derived from the survey data and used to produce utility functions. The utility functions can then be used to explore latent demand for cycle route improvements and locations (route choice and infrastructure type) (interview feedback, method developers).

Application

Demand forecasts produced by the WCDM to date have primarily been used in business cases, on a route-by-route basis. The intention is to start to use the model more strategically for cycle network master planning (ie, addressing what to build, where, and in what order) (interview feedback, method developers).

[4] Developed by Wellington City Council

Evaluation

The model has been validated to be a good fit to current cycle travel patterns (interview feedback, method developers; Pettit & Dodge, 2014, pp. 36–37). However, the forecasting aspect of the model has not yet been evaluated as none of the infrastructure projects it has been used for are complete. A benefit of this approach is that it includes the (stated) preferences of those who currently cycle, as well as potential cyclists. This means that it does not assume that the preferences of current cyclists represent the preferences of potential cyclists (interview feedback, method developers).

Future improvements

The WCDM is currently being revised, with potential changes including an investigation into improving how the model assumes preferences are spread across Wellington city. Currently it assumes preferences are evenly spread; however, in reality it is likely that preferences vary from place to place (due to residential location self-selection bias). It is also intended that in the future the demand matrix from the revised WCDM will feed in to the overarching Wellington Transport Strategy Model (which is also currently being updated), in order to improve its cycle demand forecasting (interview feedback, method developers).

3.3.3.2 WSP Modified Stated Preference Method

Background

The WSP Modified Stated Preference Method[5] (MSPM) was developed in 2014 (interview feedback, method developers).

Approach

The MSPM is a stated preference survey method that is used to test the design and route characteristics of walking and cycling facilities (scenarios) (interview feedback, method developers). The survey is developed with a range of detailed local scenarios (usually an image and description), to which respondents indicate their likely level of use for each of the scenarios. Respondents are also asked about their current walking and cycling behaviour and their potential to change. To be useful, the survey must be completed by a reasonably representative sample of the population serviced by the proposed facility. The sample is post-weighted to be demographically representative of the target population, if required. Stated current walking and/or cycling behaviour is validated and calibrated against current levels of use using local count data. Respondents are then grouped into stages of change based on the TTM (as presented in section 3.3.2.2). These groups represent how often they do (or do not) walk/cycle for transport and recreation, and how willing they are (or not) to walk/cycle for transport and recreation (interview feedback, method developers).

The respondents' stated future levels of use are then modified based on stage-matched 'reality factors', which are intended to account for the relationship between what people say they will do in the future versus what they are likely to do based on their current behaviour and potential to change (interview feedback, method developers). For those who do not currently walk/cycle for transport on any regular basis ('Precontemplation', 'Contemplation', and 'Ready for Action' stages), a conservative factor of 0.2 is used, and for those who walk/cycle regularly but infrequently ('Action' stage), a slightly less conservative factor of 0.3 is used (Bamberg, 2000). For those who walk/cycle on a regular and routine basis ('Maintenance' stage), a behavioural factor of 0.59 is used (Ouellette & Wood, 1998). Once the reality factors have been applied, the weighted sample level data is scaled to match the study population size, and annualised. This results in the forecast's level of use for the scenario(s) surveyed (interview feedback, method developers).

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[5] by WSP Research

Application

The MSPM has been used to forecast demand for cycling infrastructure in Wellington city (Island Bay to Southern suburbs route and facility design), Nelson (Rocks Road facility design), and for the location options of a walking and cycling shared bridge in Palmerston North (He Ara Kotahi) (interview feedback, method developers).

Evaluation

Of the projects the MSPM has been used for, only Palmerston North's He Ara Kotahi walking and cycling bridge has been completed (interview feedback, method developers). The forecast was produced in early 2016, and He Ara Kotahi Bridge opened in mid-2019. Walking and cycling counts from an automatic counter were captured from June 2019 to June 2020. The forecasts are compared to the count data in Table 3.2. We can see that the MSPM was reasonably accurate in forecasting levels of use for cycling; however, it underestimated walking levels substantially. This may be due to the survey design focusing on the relative utility of three bridge location options for potential users in terms of access, whereas the actual bridge has become an iconic and attractive local feature beyond what was conveyed in the survey.

Table 3.2 MSPM forecasts compared to counts for He Ara Kotahi walking and cycling bridge

	Walking		Cycling	
He Ara Kotahi Bridge forecast AADT (MSPM)	395 (overall)		543 (overall)	
He Ara Kotahi Bridge actual AADT	928 (weekday)	1,402 (weekend)	550 (weekday)	569 (weekend)

AADT = annual average daily traffic

3.3.4 Revealed preference

Revealed preference data and methods are based on choices that people have actually made. In relation to walking and cycling, this is the walking and cycling behaviour that is occurring or has occurred. It can be fully self-reported (such as completing a travel diary or survey) or it can be captured by other means, such as through counting, video capture, or GPS data from cell phones. Revealed preference data tends to be seen as being more accurate and reliable than stated preference data, as it reflects actual behaviour in a real-world context as opposed to stated behaviour or choices to a hypothetical scenario (or what people do as opposed to what people say).

However, several research participants discussed how revealed preference data can be limited in its ability to represent latent demand. Revealed preference data collected from a transport network with little to no provision for comfortable walking or cycling may not reveal most peoples' true preferences, but simply their best constrained choice they made given the options available to them at that time. It cannot reflect demand for things that do not, or not widely, exist. Additionally, route choice data collected from people who are walking or cycling in transport systems that most people would perceive to be unsafe will only reflect the route choice preferences of those who are willing to walk or cycle in those contexts. These preferences may be very different to those of people who have a latent demand for safer or more comfortable walking and cycling, as we have seen in the Chapter 2 review of walking and cycling behaviour.

Revealed preference data and methods tend to be used primarily to understand and represent walking and cycling mode choice and route choice. They tend to be based on aggregate or disaggregate data.

Aggregate demand methods are based on regression analysis of observed transport flows and trends with environmental variables, at an area or facility scale (Kuzmyak et al., 2014). Examples include the sketch plan methods presented earlier in this chapter. Other examples identified by participants in this research stocktake include the Aggregate Demand Model and the Seamless Travel Bicycle and Pedestrian Demand models developed and owned by Alta Planning and Design in the United States. More information can be found on these particular methods in Jones et al. (2010) and Kuzmyak et al. (2014).

Disaggregate demand methods are regression analysis of particular route characteristics or travel modes where the individual characteristics and behaviour are the unit of analysis (which includes discrete choice modelling) (Jones et al., 2010). While aggregate methods tend to be easier to develop and use, disaggregate models tend to be seen as being 'more effective at predicting travel behaviour' (Jones et al., 2010, p. 31) because they better reflect the components of choices for walking and cycling. It should also be noted that the WCDM in the previous section is a disaggregate demand model built from stated preference data.

Route choice models attempt to represent the way people choose the route they will take to walk or cycle from one place to another, based on the various route and traveller characteristics. They can also feed into mode choice models in order to test the effect of various network improvements on walking or cycling mode choice (Hood et al., 2011, p. 63).

This section now presents three disaggregate models based on revealed preference data, developed to represent route and mode choice behaviours of people for cycling. These approaches could also be applied to walking.

3.3.4.1 Abley Route Choice Metric

The Abley Route Choice Metric[6] (ARCM) was designed to reflect the route characteristic preferences of cyclists in Christchurch and was developed based on a similar route choice model from Portland, Oregon (Rendall et al., 2012). The Portland model developed a series of relative distance variables based on five factors found to be important to cyclist route choice: trip type, slope, intersections, cycle facilities, and vehicle volumes (on routes with no facility). The ARCM was based on revealed preference data from 2007 using travel diaries from 1,527 trips made by 400 existing Christchurch cyclists. It models cyclists' route choices for various on-route conditions (presence of path or lane, or traffic volume) and intersection types (Rendall et al., 2012). The factors for the ARCM are presented and compared to the values for Portland in Table 3.3. From this table we can see that the route choice factors vary between the two locations.

[6] by Abley Transportation Consultants

Table 3.3 Intersection and midblock route choice factors for cycling in Christchurch and Portland (Source: Rendall et al., 2012, pp. 12–13)

Facility description	Time delay (s)			
	Portland		New Zealand	
	Commute	Non-commute	Commute	Non-commute
Traffic signal*	6.1	10	3.1	5.3
Stop sign	1.4	2.6	0.7	1.3
No signal, Right turn; 10,000-20,000 vpd	26	47	13	24
No signal, Right turn; 20,000+ vpd	67	130	34	64
No signal, Left turn; 10,000+ vpd	11	19	5.6	9.9
No signal, crossing*; 5,000-10,000 vpd	12	21	6.1	11
No signal, crossing*; 10,000-20,000 vpd	17	30	8.7	15
No signal, crossing*; 20,000+ vpd	93	180	48	91

* excluding Left turns

Facility description	Time scaling factor			
	Portland		New Zealand	
	Commute	Non-commute	Commute	Non-commute
Bike lane	1.00	1.00	1.00	1.00
No bike lane; 10,000-20,000 vpd	1.37	1.22	1.19	1.11
No bike lane; 20,000-30,000 vpd	2.40	2.37	1.71	1.70
No bike lane; 30,000+ vpd	8.16	7.19	4.65	1.46
Bike path	0.84	0.74	0.92	0.87

vpd = vehicles per day

3.3.4.2 Disaggregate demand modelling for George Street Bicycle Path, Sydney, Australia

Background

A disaggregate demand model was developed to assess the George Street Bicycle Path in Sydney, Australia. This was a multimodal mode choice model (walking, cycling, public transport and motor vehicle) built from revealed preference data from a local travel survey with a GPS option, a geospatial representation of the cycle network, and rainfall data (Standen et al., 2019).

Overview

Travel survey data was collected from people living within the catchment of a proposed cycleway. The survey included a seven-day activity-based travel diary, which had an optional GPS app to track their travel behaviour. The survey was repeated again soon after cycleway completion and again just over a year later. Cyclist preference for routes with cycleways was set to be 3.1 times that of routes with no cycleways, derived from a study by Wardman et al. (2007) in the UK. Mode choice was modelled as the dependent variable in a discrete choice analysis. Forecast changes in mode share were produced for three years (2013 baseline, 2014 and 2017) for walking, cycling, public transport and by car, and for three scenarios (doing nothing, building the George Street Bicycle Path, and a complete cycle network for Sydney) (Standen et al., 2019).

Evaluation

After-count data found that peak cycle trips did increase on the George Street Bicycle Path after it opened while generally declining elsewhere in Sydney (Standen et al., 2019). Standen et al. (2017) conducted a post-completion intercept survey and found that 40% of George Street Bicycle Path cyclists said they had switched from using another travel mode since the cycleway opened. Just under half of the remaining cyclists had switched from a nearby route to use the new route. However, the travel survey diary for the catchment area did not detect a significant increase in cycling behaviour from the construction of the cycleway, in contrast to the model predictions as well as the cycle counts and intercept survey data (Standen et al., 2019). It is not clear from the data how accurate the forecasts were, as the units of presentation vary. Survey feedback for this method showed that it was seen by the method developer as being low cost and quick to use, with moderate data requirements and accuracy, but with a high level of expertise required.

3.3.4.3 Wardman et al.'s (2007) cycling mode choice model

Background

Wardman et al. (2007) developed a cycling mode choice model based on the use of both revealed and stated preference data.

Overview

Wardman et al.'s (2007) model was based on travel survey data, combined with stated preference survey data regarding the effects of route and trip-end facilities for cyclists. The model can be used to forecast the effect of infrastructure provision on the demand for cycling.

Application

Wardman et al.'s (2007) study is presented in this stocktake because it has been identified through the literature review and from the surveys and interviews as a widely used source of parameters for various demand forecasting methods. An explanation of its use for facility-level demand forecasting is provided in Department for Transport (2018).

Evaluation

No data was found to directly evaluate Wardman et al.'s (2007) model; however, the authors state that the model forecasts that a universal provision of completely separated cycleways would only result in a 55% increase in levels of cycling. Given that the data for the study is from the UK and from the 1980s and 1990s, it is possible that the parameters of the model could be updated to better reflect modern travel preferences and patterns.

3.3.5 Traditional transport models

In the past (and still commonly today), walking and cycling were often grouped together as a single 'active mode' so that they could be removed from the subsequent network analysis. Transport models have also tended to use spatial analysis zones (or Transport Analysis Zones or TAZs) at a car-centric scale, and only assign interzonal trips to the transport network, missing many shorter active journeys, particularly walking. Additionally, they have typically focused on the main mode of travel for journey-to-work trips at peak times, missing the active component of commute trips as well as active trips for all other purposes. Feedback from research respondents discussed these limitations and indicated that attempts to incorporate walking and cycling more effectively into models can be hampered by very limited data on these modes, particularly walking. One respondent also commented that the 'determinants of route choice for walking can be "too random" to model'.

The classic format of transport models is the three- or four-step trip-based models that have a simple trip origin and destination focus, typically considering the main mode and purpose of travel only. This means trip-based models do not always readily account for walking or cycling trip-legs that may be a component of a trip, such as walking to public transport (Jones et al., 2010). More recent iterations include the tour-based model with a focus on multi-stop trip chains, or 'tours' that begin and end at home. Tours thus consider all stops, trip-legs and travel modes within an overall journey. Lastly, there is the activity-based model, which views travel as a derived demand, with the ultimate goal being to reach a particular activity. Activity-based models model individual travel behaviour across a whole day, and can represent household travel interactions (Bradley et al., 2019). Tour- and activity-based models are more data and resource intensive than trip-based models; however, they tend to also be seen as a better representation of complex human travel behaviour (Bhat & Koppelman, 2003; San Francisco County Transportation Authority [SFCTA], 2020). No examples of tour- or activity-based transport models were identified in New Zealand, and their use appears to be most prevalent, or at least well documented, in the United States.

The four-step trip-based model has been recently described as the 'mainstay of transport modelling in New Zealand' (Smith, 2019, p. 44). The four-step modelling process includes:

1. Trip generation (How many trips?)
2. Trip distribution (Where do trips go?)
3. Mode split (How do people travel?)
4. Assignment (What route will be taken?) (Jones et al., 2010, p. 31).

The first step – trip generation – involves calculating the number of trips, by purpose, that begin and end in each zone (or spatial unit) over a defined time period (such as over 24 hours, am or pm peak, or inter-peak). The second step – distribution – involves estimating the number of trips between each zone, which is produced as a trip matrix. The mode split step involves disaggregating the inter-zonal trips by mode of travel. In the fourth and final step the inter-zonal flows are assigned to the transport network. Models that skip the mode split step are called three-step models. It is also important to note that not all transport models have a forecasting capacity (Smith, 2019).

There were mixed levels of confidence among research participants in the output from modelling approaches, with some respondents feeling they produced the most reliable forecasts and others feeling that they gave a false sense of certainty. In reality, not all models are the same, nor are they inherently accurate or inaccurate, but the accuracy of any model is dependent on the quality of the data and the robustness of the parameters of the model.

Most of the modern walking and cycling models identified by this research have been 'enhanced' in various ways to make them more suitable for walking and cycling behaviour. Several models were identified by survey respondents that have not been discussed in detail in this report, either due to limited information being available or because the model was not (yet) demonstrated as suitable for modelling latent demand for walking and/or cycling. Examples include the Western Australia Strategic Transport Economic Model (STEM), which models walking and cycling but is currently not seen as accurate enough yet to be used to forecast demand for projects (survey response, general stakeholder). The STEM is being updated over the next couple of years to attempt to improve active mode forecasting. Another model identified by a survey respondent but not discussed here is the Brutus Mobility Model.[7] This appears to be a multimodal activity-based simulation model, but very little information was provided or available in a literature search. Several research participants discussed cycle demand models produced for Melbourne;[8] however, the research team was also unable to gather more information on this approach. One other Australian model[9] was identified as

[7] by Straficka in Finland and Mobycon in the Netherlands

[8] by the Institute for Sensible Transport

[9] TransPosition's 4S model

a potential tool by some participants, but its application to latent demand forecasting for walking and cycling was not specifically identified.

The walking and cycling models identified are now presented.

3.3.5.1 Auckland Cycle Model

Background

The Auckland Cycle Model (ACM)[10] was developed in 2015 with the objective of meeting the need for improved cycle demand forecasting methods (Jongeneel, 2017).

Development

The ACM was based on 2013 Census journey-to-work data, factored up to account for non-work trips using Auckland household travel survey data, and about 400 cycle count data points (both manual and continuous automatic counts). The 2013 base model was then validated against 400 additional cycle count data points and was found to be a good fit. The ACM responds to changes in land use and the cycle network and considers all trips that could potentially be cycled, based on trip length and trip type. It represents major transport network routes with more detail in the city centre. Latent demand for new infrastructure is modelled through existing cyclists re-routing as well as new trips generated. The model also accounts for future land use (increasing cycle trips in response to land-use intensification as well as new land uses), population and employment changes (Jongeneel, 2017).

The route choice model considers the ‘relative attractiveness’ of routes, which is a combination of the type of facility and its perceived safety (safety/comfort), trip distance, and gradient. The mode choice model includes the likelihood of a non-cycling (but potentially cyclable) trip transferring to cycling, based on similar factors included in the route choice model (Jongeneel, 2017).

New cycle trips are assessed based on existing car and public transport trips (taken from the Auckland Regional Transport model) to identify which ones could potentially be made by bike (based on trip purpose and distance). The model then applies demand elasticities to shift a small portion of these trips to bike if the route for that trip has been improved by cycling infrastructure. These elasticities were developed by Flow based on international evidence of the demand response to cycle infrastructure (Jongeneel, 2017).

Application

The ACM has been used to forecast latent cycling demand for most major Auckland cycle projects since 2015 (survey feedback, method developer). Some of these projects are complete and the forecasts have been evaluated.

Evaluation

The 2016 model forecasts were compared to 2016 annualised automatic count data from sites around Auckland that had completed significant cycling infrastructure investments, as well as to sites that had not had infrastructure improvements, since 2013. The results showed that background growth rates on unimproved routes were 16% based on the count data, compared to 22% modelled, and a step-change increase in cycle volumes occurred on improved routes (101% based on count data compared to 121% modelled). Additionally, the model was found to predict the pattern of cyclists re-routing to nearby improved

[10] by Flow Transportation Consultants Ltd

routes and gave reasonable predictions for some completely new routes that had no initial count data (Jongeneel, 2017).

Based on the 2016 count data, the model was refined. The refined 2016 model forecasts were then compared against two other sketch plan forecasting methods (see Table 3.1 in section 3.3.1.2) for six new or improved cycle routes in Auckland. The ACM had the least error of the three methods (average of 14%, ranging from −23% to +29%) (Jongeneel, 2017). Feedback on the ACM from a respondent associated with the development of the model identified that the ACM was resource intensive to develop in terms of cost, time, data and expertise. However, the perception was also that it offered a high fit for purpose and moderate accuracy. The ACM was seen as having a low transferability to other places, likely reflecting that it was built to Auckland-specific data.

3.3.5.2 Tauranga Cycle Model

Background

The Tauranga Cycle Model (TCM)[11] was recently developed to assess demand for a completed cycle network (survey feedback, method developer).

Approach

The TCM was built using outputs from the Tauranga Regional transport model, including trip matrices and generalised costs of travel. This was combined with travel behaviour data from the household travel survey, census data, manual and automatic count data, and the United Kingdom Department for Transport National Travel Survey. It also includes land-use forecasts, and data representing cycling infrastructure and high-level level-of-service criteria. The TCM can forecast both cycling and electric cycling trips, and the developers have explored the potential option of expanding to cover electric micro-mobilities (but currently it cannot do this) (survey and interview feedback, method developer).

Application

The TCM has been used to assess Tauranga's cycle investment programme as well as the Totara Street cycleway.

Evaluation

Post-implementation count data is not available yet, so the forecasts have not been assessed for accuracy, although the intention is that they will be once they are available. An individual associated with the TCM said the model was resource intensive to develop and use, with a high level of expertise required. It was also seen to be highly fit for purpose.

3.3.5.3 Auckland Strategic Active Mode Model (SAMM)

Background

The Auckland Strategic Active Mode Model (SAMM)[12] is a four-step trip-based strategic transport model (Murray & Subba, 2019). The initial model development was completed mid-2019, and it is currently considered a 'first generation tool' being tested by the Auckland Forecasting Centre (interview feedback, general stakeholder).

[11] developed for Tauranga City Council

[12] developed for the Auckland Forecasting Centre

Purpose

The SAMM is a strategic active-travel demand model for the entire Auckland region. It has been designed to assess demand response to changes in walking and cycling infrastructure, as well as demographic changes, and in response to changes in travel by other modes (public transport and driving) at a regional level (Murray & Subba, 2019).

Development

The SAMM incorporates land use, the transport network, and a refined zone system from other Auckland Forecasting Centre models. It represents daily travel for a typical weekday and a range of trip types. It only represents walking and cycling trips if they were the singular travel mode (ie, if they did not have a car or public transport component, except for active trips with a ferry component, which were included). However, multimodal trips are represented in other Auckland Forecasting Centre models. Only trips with a transport purpose are included, but the model can also estimate recreational flows on key recreational/scenic routes (Murray & Subba, 2019).

Key data sources used to develop the model were 2013 Census journey-to-work data, 2006 New Zealand Household Travel Survey data, selected 2016 and 2018 cycle count data, and a sample of cycle trip GPS data taken from the Strava app (Murray & Subba, 2019).

The model includes a function to modify trip production and attraction to account for accessibility of the location. It uses a generalised costs function measured by travel time. Travel time is adjusted to account for user perceptions of facility type, type of road, route amenity and hilliness for cycling, and route amenity and hilliness for walking. ‘Use of such costs mean that the cycle demands will respond to changes in the speed, quality, amenity and hilliness of each section, while walking will respond to amenity and hilliness’ (Murray & Subba, 2019, p. 3). Cycle trips are segmented into three groups with different cyclist types reflected through ranges of travel speed and facility preferences.

The 2016 base year model was validated using count data, and year 2018 forecasts were produced using input from other models and the 2018 active mode network. This further refined and validated the base year model fit. The 2018 model was able to predict travel flows on new active transport facilities to a satisfactory level. Individual link flows for walking are not considered reliable, and total demands should be used. However, individual link flows can be used for cycling (Murray & Subba, 2019).

Future developments

The model developers have several intentions for the SAMM in the future, including evaluating the model’s demand response to new facilities, to keep updating the model with new data, and also to consider adding in background growth trends to reflect changes not attributable to the network characteristics (interview feedback, general stakeholder).

Application

At the time of data collection for this research, this model had not been applied to projects as it was being tested. The model developers note that additional local data and calibration may be required in order to use the model for the assessment of some projects.

Assessment

The model was assessed for how well it predicted a change in cycle counts between the base year 2016 and the forecast year 2018 for new cycling facilities constructed within that time. Although there was some variation between forecasts and counts on individual facilities, the overall growth factor across the sites was a good match (1.37 for counts, 1.40 for model forecast, 2018:2016). Model users said the SAMM was moderately resource intensive to develop and use, requiring a high level of expertise and technology. It was also seen as being moderately accurate and fit for purpose.

3.3.5.4 Canberra Strategic Transport Model

The Canberra Strategic Transport Model[13] is a traditional transport model that models vehicles, public transport and cycling (survey feedback, general stakeholder). It is based on household travel survey data, demographic census data, and the transport network, including cycling infrastructure. It includes a factor to represent the preference for off-road versus on-road cycle facilities. It has been applied to the development of a cycle network strategy and assisted in the prioritisation of projects. It has not yet been evaluated using post-construction count data; however, before-data was collected, and the intention is to evaluate the model once the cycle facilities are built (survey feedback, general stakeholder).

3.3.5.5 Auckland City Centre Pedestrian Demand Model

Background

The Auckland City Centre Pedestrian Demand Model (ACCPDM)[14] was developed for Auckland city centre and has been used on projects for Auckland Transport and Auckland Council (survey feedback, method developer).

Method overview

The ACCPDM is a spreadsheet-based walking model with route and destination choice features that estimates existing walking activity and projects future walking activity. Data sources for this model include:

- existing pedestrian counts (manual and automatic)
- current and future forecast public transport boardings and alightings (from Auckland Transport HOP data and Auckland's Macro Strategic Model)
- current land use from census data
- forecast land use (from the Macro Strategic Model)
- information about structure of the walking and public transport networks (survey feedback, method developer).

Application

This approach was applied to estimate future pedestrian volumes for improvements on Wellesley Street, Quay Street, and for the street network between Quay Street and Customs Street in Downtown Auckland (survey feedback, method developer).

Evaluation

The relevant projects are still to be implemented or are under construction, so post-implementation data has not been captured (survey feedback, method developer). The method developers said that it was low-cost to develop and took a moderate amount of data and time to use. It was also seen as being low-tech but requiring a moderate to high level of expertise to use.

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[13] owned by the Australian Capital Territory government

[14] by MRCagney

Future improvements

The ACCPDM is currently being developed into a GIS-based model. This makes it easier to model a larger area of the walking network; for example, the whole of the city centre as opposed to several streets. It also allows the inclusion of features such as gradient and intersection delay in the model (survey feedback, method developer).

3.3.5.6 Wellington Walking Demand Approach (*in development*)

Background

The Wellington Walking Demand Approach[15] is currently being developed to assess walking demand in Wellington City (interview feedback, method developer). This approach is being designed to assess walking demand for three types of walking trips, with data taken from the New Zealand Household Travel Survey. The trip types being assessed are:

1. those with a city-centre origin (about half of Wellington walking trips)
2. those that start and end outside the city centre, but one point of the trip is home-based (about a quarter of Wellington walking trips)
3. those that start and end outside the city centre, and none of the trip points are home-based (also about a quarter of Wellington walking trips) (interview feedback, method developer).

Overview

For the walking trips with a city centre origin, Wellington has a City Centre Walking Flow Model. Interview feedback indicates that this model represents existing walking flow patterns and general growth trends quite well. However, limitations of the City Centre Walking Flow Model are that there is no origin and destination point data for the trips, and that it does not forecast latent demand. However, it was described as being sufficient because the city can usually justify investments based on existing demand and growth trends (interview feedback, method developer).

For the suburban walking trip types, trip generation is taken from Household Travel Survey data. This was described as being very hard to validate, as walking flows are low. Intentions are to then overlay this walk trip data with the existing walking network infrastructure to better understand walking preferences. Once this is complete, the findings from a recent stated preference discrete choice survey will be incorporated into this model. The survey traded walking time against various walking facility characteristics, with a focus on trip characteristics that can be changed (ie, improvements that can be made). One finding from this study is that people get utility gains from increases in walking trip times, which does not fit the typical assumption that increased travel time is always a cost (interview feedback, method developer).

3.3.5.7 Wellington Transport Strategy Model

The Wellington Transport Strategy Model (WTSM)[16] is the overarching transport model for Wellington. The WTSM was originally built in 2001 using Household Travel Survey data. It has gone through several updates since then, and it is regularly calibrated to observed data. It is currently being updated (interview feedback, general stakeholder). The WTSM is a four-step, trip-based strategic transport model. It is multimodal, covering vehicles, public transport, and walking and cycling; however, walking and cycling are grouped

[15] by the Wellington City Council

[16] by the Greater Wellington Regional Council

together as an ‘active mode’. The active mode is currently skimmed and not distributed to the network; however, the intention is to distribute these trips in the future.

Research respondents discussed that the main current limitation of the WTSM, and models like it, is the large zone size. The WTSM currently has 225 zones, but that is being increased to 800 zones, which will make it more suitable for modelling walking and cycling trips (interview feedback, general stakeholder).

3.3.5.8 Christchurch Strategic Cycle Model

Background and application

The Christchurch Strategic Cycle Model (CSCM)[17] was developed and applied to Christchurch’s major cycleway routes for the strategic case and programming, as well as used for the design and funding applications for individual projects (survey feedback, multiple stakeholders).

Method overview

The CSCM is based on the city’s existing traffic model (the Christchurch Assignment and Simulation Traffic model), which has a TAZ size and a level of transport network representation suitable for modelling cycling. The CSCM takes account of forecast future changes in demographics, population and land-use patterns, traffic congestion, and fuel prices as well as people’s perceptions of the utility of cycling and attractiveness of various network improvement packages (Roberts, 2014). The model was calibrated to cycle count data. The CSCM uses a factor of 30% to estimate the maximum proportion of car users who would actually choose cycling as a viable alternative if given suitable improvements. This is identified by the model developers as a key assumption for the future cycle demand estimates, and an area that will be reviewed over time (Roberts, 2012). More detailed information about the CSCM can be found in Roberts (2012, 2014, 2015).

Evaluation

Post-construction count data is now available for many of the major cycleway projects; however, a survey respondent (general stakeholder) pointed out that the forecasts are difficult to evaluate because what was built is ‘somewhat different’ to what was modelled. Additionally, the research team for this project did not have access to the facility-level forecasts in order to evaluate them.

Developers and users of the CSCM said the model was low to moderate cost and took a moderate amount of time to develop and use. It was seen to be moderate in terms of data use and technology and required a high level of expertise. It was also seen as being moderate to high in terms of fit for purpose.

3.3.5.9 MoPeD

Background

The Model of Pedestrian Demand (MoPeD) was developed to improve pedestrian representation within the current four-step model for Portland, Oregon (Clifton, 2016).

Overview

The MoPeD method models walking trips at a very fine spatial scale, with very fine-level spatial representation of the built environment. It incorporates research into pedestrian behaviour and can be incorporated into a regional model or used as a stand-alone model. It is built on household travel survey data and employs the Pedestrian Index of the Environment (PIE) as a walkability indicator. This captures the

[17] developed for the Christchurch City Council

aspects of the built environment known to influence walking. Each variable is weighted by how well it explains the likelihood to walk. Within MoPeD, the choice to walk is a function of traveller characteristics (household size, income, age, number of workers, number of children, number of vehicles) and the built environment score (PIE) (Clifton, 2016).

Evaluation

The model developers found the model was accurate in modelling walking mode choice. Destination choice with MoPeD is modelled as a function of factors such as distance, destination density and characteristics, PIE, and traveller characteristics. The model was accurate for destination choice about half of the time and tended to underestimate walking distance (Clifton, 2016).

Future developments

Future developments for MoPeD include testing the method in other areas, refining the forecasting inputs, and exploring non-linear effects and other interactions for destination choice. Areas for further research identified by the method developers included understanding pedestrian route choice better to improve modelling (Clifton, 2016).

3.3.5.10 The London Walking and Cycling Modelling Approach

A suite of five strategic models[18] are used to represent multimodal travel, including both walking and cycling, across the London transport network. The models are often used in an interactive way to aid planning and decision making (TfL Planning, 2020).

The London Transportation Studies model

The core model is the London Transportation Studies model, which is a traditional four-step transport model based in the transport modelling software ‘Cube’, which was developed by Citilabs. It uses population and employment forecasts to predict future travel volumes, origin and destination locations, time and mode of travel (including walking or cycling), and network distribution. This model has been developed over decades and incorporates an extensive dataset. The output of the London Transportation Studies model is used as an input into the other four models, including Cynemon, which is cycling-specific (TfL Planning, 2020).

Cynemon

Cynemon is London’s strategic cycle model and is also based in Cube software by Citilabs. It has been designed to model and visualise current and future cyclist volumes, travel time, and route choice across London for weekday peak and interpeak travel. The route choice model component considers gradient, the type of road and traffic volumes, and cycling infrastructure. It can also forecast latent cycling demand, as well as mode shift, from investment in new cycling infrastructure. Information for the model includes data on the transport and cycling network, cycle demand, and cycle route revealed preferences (online survey and GPS), with information taken from a range of sources (Davies, 2017).

3.3.5.11 SF-CHAMP Model

The San Francisco Chained Activity Modeling Process (known as SF-CHAMP) is a regional travel demand activity- and tour-based transport model. The initial model was developed in 2002, and the model is still in active use. SF-CHAMP can model the effects of changes in land use, socioeconomic characteristics, and the

[18] by Transport for London

transport system, and also considers how these changes may impact transport patterns and flows (SFCTA, 2020).

It is built from data that represents San Francisco’s:

- residents’ observed travel data
- transport network, including roads and transit (present and future)
- land use (present and future)
- population and employment characteristics (present and future) (SFCTA, 2020).

Cycle route choice sub-model

The bicycle route choice coefficients for SF-CHAMP were developed from revealed preference data collected by a GPS-based smartphone app used by cyclists in San Francisco (Hood et al., 2011). This route choice model failed to reveal an association between factors that one would assume to be important to cyclist route choice, such as volume of traffic, which is identified as an important factor in other studies. The authors’ view is that the revealed preference approach had failed to separate the effects of related covariates, which ‘underscores the importance of employing both stated and revealed preference methods to obtain a complete picture of traveller behaviour’ (Hood et al., 2011, p. 72). The app used by the SFCTA to look at cyclist route choice[19] and the code for the bike route choice model[20] are open source, and the anonymised data collected from the app is available for other public agencies. The Cycletracks app is currently being used by 10 other US cities, and modified versions are being used by eight other US cities (Hood et at., 2011).

3.3.6 Geospatial assessment

This section presents latent demand estimation methods for walking or cycling that are substantially geospatial based, either in processing information and/or presenting. Geospatial-based approaches were strongly encouraged by Kuzmyak et al. (2014) because of their ability to represent spatial data at a fine scale, as well as their ability to spatially represent complex urban form and transport network characteristics. Kuzmyak et al. emphasise that GIS may be the ‘principal technological factor enabling the analysis of bicycle and pedestrian behaviour’ (p. 3). Geospatial approaches have not extensively been used in a New Zealand setting; however, there are cases where they have been (presented below). Transport for London and the United Kingdom Department for Transport were found to have a strong geospatial approach to the assessment of walking and cycling demand, where outputs from demand forecasting models are one aspect of the wider spatial assessment. These approaches are also presented below.

3.3.6.1 London’s geospatial assessment of cycling potential

London city undertook comprehensive geospatial analysis on cycling potential that was used to identify and strategically prioritise improvements on key missing links in the cycling network (Transport for London, 2017). This assessment was carried out in a GIS by overlaying multiple spatial datasets, including from the London Transportation Studies and Cynemon models (presented in section 3.3.5.10), with various other information, including:

- routes with high levels of existing cycling demand

[19] See: https://www.sfcta.org/tools-data/tools/cycletracks

[20] See: https://github.com/sfcta/BikeRouter

- routes with the greatest opportunity for mode shift from vehicles to walking and cycling (based on trip type and distance)
- places where groups of people with latent demand for cycling were located based on the Transport Classification of Londoners tool (as discussed in section 3.3.2.5)
- places where population and employment growth were expected to occur in the future
- walking and cycling safety analysis
- public transport accessibility
- placemaking (Transport for London, 2017).

3.3.6.2 The United Kingdom Propensity to Cycle Tool

Background

The Propensity to Cycle Tool (PCT)[21] is 'a method for modelling and visualising the spatial distribution of cycling flows, currently and under various scenarios of "cycling futures"' (Lovelace et al., 2017, p. 521). The PCT is a transport planning system that employs open-source data and software and delivers a publicly accessible map-based interface, which means its inner workings are transparent and it can be freely copied or modified for use in other places (Lovelace et al., 2017).

Overview

The PCT addresses the question of where to build facilities to cater to the most potential cycling growth. It does this by identifying which trips could most easily be converted to cycling, employing origin–destination-level travel data based on trip distance and hilliness. It projects local, route-level demand, based on a range of cycling population level-of-use potential scenarios, and allocates this potential onto the road network using desire lines based on a 'routing algorithm specifically developed for cycling' (Lovelace et al., 2017, p. 509). The scenarios are not forecasts of future use; they are 'snapshots indicating how the spatial distribution of cycling may shift as cycling grows based on current travel patterns' (p. 512). For example, it can estimate the spatial distribution of cycle flows if England had the same cycling rates as the Netherlands, or if e-bike use made cycling more attractive for longer and hillier trips.

The results can be presented at a range of geospatial scales, from area level to network level, down to street level. For each potential future scenario, it also estimates the total health and carbon benefits (Lovelace et al., 2017). The tool is currently available for use and is also still actively being developed and updated on an ongoing basis (survey respondent, method developer).

Application

The PCT was used by over 50 local authorities in the UK in 2019 (survey respondent, method developer). The PCT development team also developed the Cycling Infrastructure Prioritisation Toolkit (CyIPT), which is presented later in this section.

The PCT was rated by a survey respondent (method developer) as being of moderate cost and a high amount of time to develop, but quick and requiring a low level of expertise to use. It was seen as moderate in terms of accuracy and the data and technology required, but also as being highly fit for purpose and transferable.

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[21] The PCT is funded and owned by the United Kingdom Department for Transport, with intellectual property retained by the University of Cambridge. See https://www.pct.bike/

3.3.6.3 Seapath Propensity to Cycle Assessment

A propensity to cycle assessment was undertaken in New Zealand, based on the PCT approach. This was done in order to generate a range of potential future-use estimates for the Auckland Seapath detailed business case (survey and interview response, method developer). This assessment took account of a range information, including:

- bikes and e-bikes
- travel behaviour
- land use
- level of service
- proximity and gradient
- transport network and access (survey response, method developer).

This approach was rated by a survey respondent involved in the method as being low cost and low tech, taking a moderate amount of time to develop and use, and a moderate level of expertise and accuracy. This respondent also saw it as being highly fit for purpose and transferable.

3.3.6.4 Cycling Infrastructure Prioritisation Toolkit

Background

The Cycling Infrastructure Prioritisation Toolkit (CyIPT)[22] is currently a prototype that was completed in 2018 (Lovelace et al., 2020).

Overview

CyIPT is open-source software that was designed to complement the PCT, with the PCT estimating the potential for cycling and where to prioritise network building, and with CyIPT focusing on what to build and how to prioritise what is built first (Lovelace et al., 2020). CyIPT draws information on potential future demand from the PCT and combines this cycle demand information with information about the road network, such as speeds, traffic volumes and road types to recommend the most appropriate type of cycle infrastructure for every road in England. It can then group geographically coherent and complementary improvements into ‘schemes’ for which it can then estimate construction costs, cycle demand uptake and benefits, and benefit–cost ratios. CyIPT’s uptake model, which estimates the increase in levels of cycling on a route following the creation of appropriate infrastructure, was developed from a UK cycle count dataset from cycle infrastructure improvements made between 2001 and 2011.[23] Factors in the uptake model include the level of cycling potential (or high latent demand), type of infrastructure, and traffic speeds on the roads before/after the new facility (Lovelace et al., 2020). The uptake model found that

> *low speed limits of the route were a powerful predictor of cycling uptake following new infrastructure. To model this the percentage of the route at different speed limits was used as an interaction variable that diminished the effectiveness of new infrastructure for fast (40mph+) roads and increased the effectiveness of new infrastructure in cases where the percentage of the route that was on low speed limit roads was high. (Lovelace et al., 2020, Report > Method).*

[22] funded by the UK Department for Transport

[23] The data source for the uptake model is available at https://github.com/cyclestreets/dft-england-cycling-data-2011

No information was found regarding the application or evaluation of CyIPT.

3.3.6.5 ViaStrada Cycle Route Network Planning

Background

The ViaStrada Cycle Route Network Planning tool was developed as an objective way of identifying locations where cycle routes or networks may serve the most people. It is GIS-based to aid in the management, analysis and presentation of spatial data (Macbeth et al., 2007).

Overview

This approach does not quantify latent demand, but explores geographic factors (such as population, and origin and destination variables) to assess where cycle lanes may be most warranted. Data used in this assessment included general urban topography, the road network, transport model zone boundaries, population, employment and educational data, and cycle crash data. Analysis of existing and proposed cycle facilities was undertaken to assess the location of routes to serve the greatest number of people (urban activity and potential cycle trips). The Cycle Route Network Planning tool was used to evaluate potential networks in Auckland and Melbourne cities (Macbeth et al., 2007).

3.3.6.6 Future demand patterns for cycling in Christchurch

Background

Martin (2015) used GIS and associated network analysis tools to explore future demand patterns for cycling in Christchurch, and how cycling-specific infrastructure could cater to these patterns.

Overview

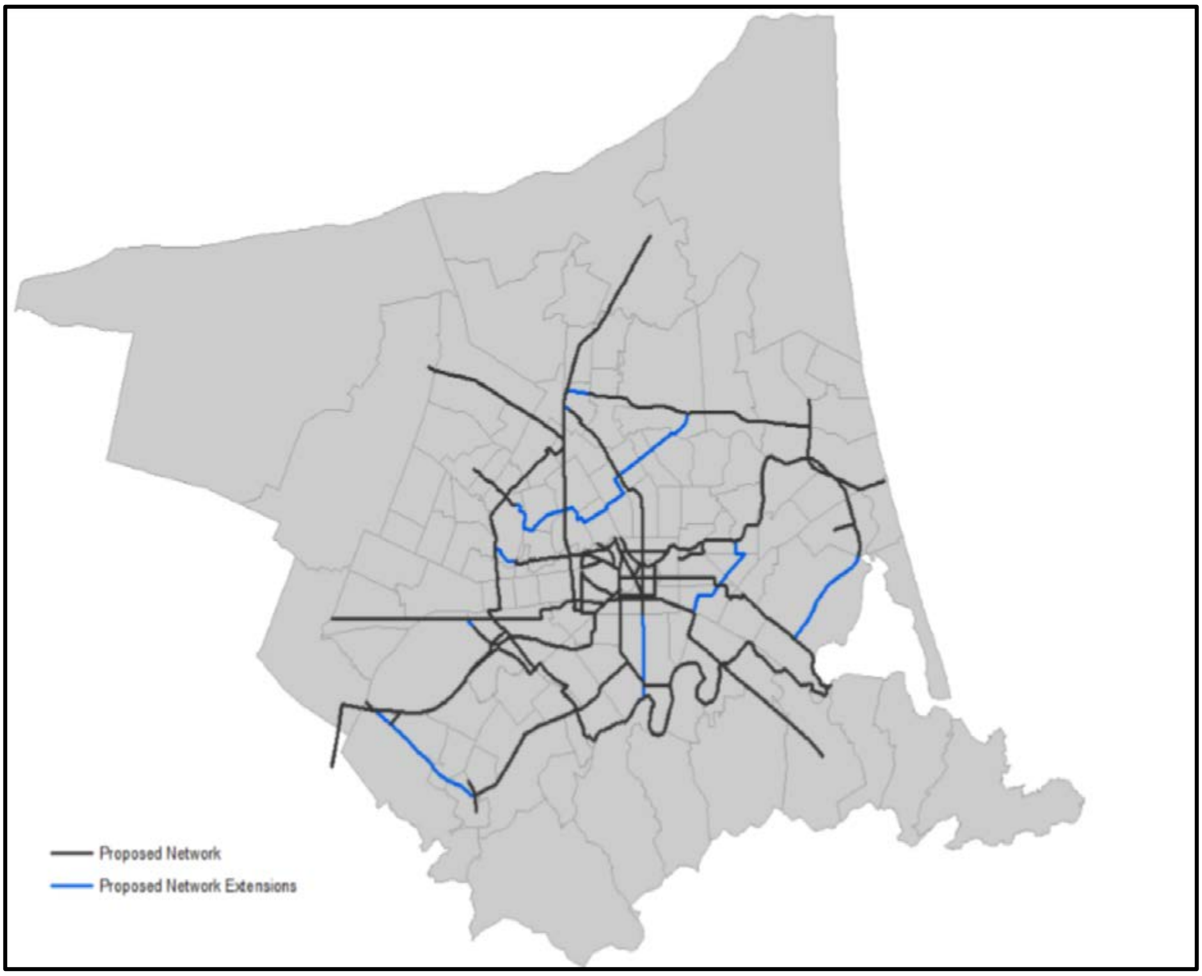
The research project employed various data sources including projected employment and population data for year 2041, zones from the Christchurch Assignment and Simulation Traffic Model and the Christchurch Transport Model, and property title, transport network and volume information. The data sources for this information were Christchurch City Council, Land Information New Zealand, and Stats NZ (Martin, 2015).

Application

The study used GIS extension analysis and modelling software to project likely future transport volumes based on future population and economic growth, and then evaluated likely route choices for cycle trips by applying weightings from the Abley Route Choice Metric (see section 3.3.4.1) (Martin, 2015).

Spatial analysis was then used to identify areas within Christchurch that would likely be under-served by Christchurch’s major cycleway routes in the future. Cycle network extensions were proposed for these areas. Latent demand for the proposed cycle network extensions was calculated based on the resident population density within a buffer zone of the new facility, as per Raith et al. (2011) (Martin, 2015). The proposed cycle network extensions from this study are shown in Figure 3.4.

Figure 3.4 Cycle network extensions for Christchurch based on an assessment of future cycle demand patterns by Martin (2015, p. 80)



3.3.7 Accessibility

Some survey and interview research participants raised the possibility of using particular accessibility models to assess demand for walking and cycling, due to evidence they had seen of a relationship between accessibility models and demand.[24] Additionally, accessibility measures have been associated with travel mode in the literature (eg, Kuzmyak, 2014). However, the research team could not identify any specific application of these methods to assess or forecast *latent* demand for walking and cycling. They can assess where accessibility is low, thus implying that improvements to accessibility for those places may increase levels of demand.

Vale et al. (2016) recently conducted a systematic review of accessibility assessment methods for walking and cycling. The authors conclude that 'ways to measure active travel accessibility are very diverse, and there is little agreement on theoretical and methodological concepts and assumptions' (p. 227), although they do find that there are categories of types of accessibility assessment.

[24] Accessibility models specifically mentioned by participants include the Queensland Department of Transport and Main Road's Land Use Public Transport Accessibility Index (LUTPAI) model and TransPosition's 4S model (both multimodal accessibility models), and Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS) (a public transport accessibility model).

Further research into the relationship between various accessibility measures and walking and cycling demand, and their potential to assess latent demand, may be warranted, addressing questions such as:

- Which of the accessibility methods may be most associated with walking and cycling demand?
- What level of sensitivity may they have to changes in walking and cycling provision?

3.3.8 Spatial dynamics

Spatial dynamics models were also raised by participants; however, as with accessibility models, the research team could not identify any specific application of these methods to assess or forecast *latent* demand for walking and cycling. However, such models may offer value at a strategic level to represent and understand complex system interactions within the built environment and transport system.

3.3.9 Limitations of, and cautions for, latent demand forecasts

Six main themes related to limitations and cautions of latent demand forecasts emerged from respondent feedback in the survey and interviews:

1. The potential to reflect and exacerbate inequities
2. Forecasting effort versus value
3. Knowledge and data limitations
4. The unknown future
5. Forecast evaluation limitations
6. Predicting versus setting a target

These themes can apply to demand forecasts in general and are not specific to any particular forecasting method.

3.3.9.1 The potential to reflect and exacerbate inequities

Some respondents pointed out the possibility that walking and cycling demand forecasts may reflect existing patterns of transport system inequity, and therefore basing investments on them risks potentially further exacerbating inequities. An example given was that current demand forecasting methods are often based on more affluent populations, and thus not always fit for purpose for lower socioeconomic areas, where there may be a less established walking or cycling culture. This is an important area of consideration for practitioners and policymakers, and potentially an area where further research could add value.

3.3.9.2 Forecasting effort versus value

Some respondents emphasised the importance of balancing the effort and cost of producing a reliable demand forecast with the value it provides, with one stating: ‘You can spend a lot of money on demand forecasting, but is this what you want to spend your money on?’ Another respondent pointed out that there may be instances where an inaccurate walking or cycling demand forecast is merely ‘academic’, due to typically low volumes. However, it was pointed out by another respondent that reliable forecasts are especially important for investments where the lifespan of the infrastructure is longer-term and for where there may be potential capacity constraints over that lifespan, such as on bridges.

3.3.9.3 Knowledge and data limitations

Research participants frequently commented that the biggest constraint in producing quality walking and cycling demand forecasts is a lack of knowledge and data. This includes limitations related to walking and cycling data, such as data availability and quality, as well as knowledge about what variables are important to consider relative to demand, and how they interact in different spatial and temporal contexts to accurately forecast levels of use.

One international academic survey respondent emphasised that ‘the evidence on cycling uptake is key, we need more research on “dose response” rates’. Many respondents thought there was a need for better before and after data case studies to be collected and shared in order to gain insights into the ‘dose-response’ rate for investments. This could be useful to inform future walking and cycling infrastructure investments.

These findings are supported by the literature, which emphasises that the quality of the data available has a substantial effect on the quality of the latent demand estimates (Jones et al., 2010), and that the considerable body of research into factors associated with walking and cycling behaviour and behaviour change has (until perhaps more recently) not been widely applied to practice (Kuzmyak et al., 2014). The implication of this is that the accuracy of any particular method is not necessarily ‘inherent’ but is dependent on having a sufficient quality and quantity of data.

Additionally, modellers involved in more complex transport model type approaches for walking and cycling commented that the model guidance in New Zealand is not suitable for walking and cycling models (eg, the validation criteria).

3.3.9.4 The unknown future

Another common issue raised by respondents is that many forecasts cannot readily and reliably account for factors of the unknown future. Common examples include new and disruptive emerging phenomena, such as new transport technologies (eg, electric bikes and shared micro-mobilities), or cultural step-changes and social tipping points whereby past behavioural trends no longer apply (eg, shifts in the demographic trends or the underlying preferences of people towards walking and cycling).

3.3.9.5 Forecast evaluation limitations

The vast majority of the demand forecasts produced by the methods and projects identified in this research had not been (or had not yet been able to be) evaluated using after-count data to assess accuracy. Evaluation of accuracy could include assessing the average of, and variation in, error across cases. Evaluation of methods and forecasts could also include an assessment of the potential for bias – that is, whether any error is also unfair or inequitable.

Where the methods or projects have been evaluated, the sample is often very small. One interview participant pointed out that ‘demand forecasts are a requirement as part of a business case, but there is typically no evaluation. Once the new infrastructure is built, the project is closed.’ Others emphasised that forecast accuracy cannot always easily be assessed for various reasons, including that:

- what ends up being built may be very different to the infrastructure design that the forecast was based on
- pre- and post-implementation counts may not be easily comparable, and can be subject to wide variation, due to a range of known and unknown factors, including:
  - the weather, season, time of day, and day of the week
  - the point/s along the route/s or network where the count takes place
  - the method of data collection (such as manual or automatic, regular or one-off, discrete or continuous).

3.3.9.6 Predicting and providing versus target setting

The use of forecasts in all forms of transport planning can be controversial, with one main critique being that predicting future transport dynamics based on projecting patterns from the past, and then providing a transport system based on that information, results in a self-fulfilling prophecy whereby the outcome can be a direct result of the prediction itself (Schaeffer & Scalar, 1975).

To highlight this point, one stakeholder respondent discussed that the Dutch, who are widely viewed as having some of the most advanced walking and cycling infrastructure in the world, did not create this with consideration of latent demand forecasts. Like many other places in the world, from the mid-1900s rates of active transport in the Netherlands were plummeting, and car-centric transport infrastructure was being developed through cities to cater for high volumes of car use. If active transport latent demand forecasts had been used at this point to inform the design of their transport infrastructure, it seems likely that Dutch cities would look more like the car-oriented cities of much of the rest of the world today. Instead, it was a social uprising in protest of the safety impacts and loss of streets for people of this re-orientation for car traffic that led to a surge in political support and to the creation of the walking and cycling infrastructure and culture that is so highly regarded today.[25]

Some respondents challenged the role of demand forecasts that project past trends to see 'what is possible' in the future, instead arguing that decision making should be vision-based, in that the decision is made to achieve a particular result or target (such as a level of service, amenity, or safety, or a certain mode share), and a plan is then made to achieve that result. Others pointed out that both approaches can be used in a complementary way, where the desired outcome may be set using a target-setting approach, and where demand forecasts can be employed to support decision making around planning and prioritising investment.

3.4 Stocktake summary

From the review in Chapter 2, it is clear that a range of factors are associated with walking and cycling behaviour and behaviour change. These can include individual- and household-level factors such as perceptions, sociodemographic characteristics, capability and competency, and trip purpose. Environments can also be important; in particular, active transport infrastructure, the built and natural environment, and society and policy contexts. However, it is also clear that the factors influencing walking and cycling behaviour can vary substantially from place to place, perhaps indicated by active transport maturity. How infrastructure changes affect individuals and communities will therefore be a reflection of many factors, as well as the intended intervention itself. The implication of this for walking and cycling latent demand estimation methods is that the transferability of data, factor associations, and parameters between places must be assessed carefully. The review also showed that while the determinants of walking and cycling may overlap in some instances, they diverge in others, and also that the strength of association varies between modes. Methods for estimating latent demand for walking and cycling must therefore consider the modes separately in order to adequately represent them.

Chapter 3 reviewed and assessed the range of methods used over the past decade to estimate latent demand for walking and cycling. Data and the application of methods were more available and advanced for cycling than for walking. Firstly, a conceptual framework was proposed to assess latent demand estimation methods based on what goes in, the process it goes through, and what comes out. This led to the categorisation of latent demand estimation methods for walking and cycling into groups. Explanations were

[25] See, for example, 'How Amsterdam became the bicycle capital of the world':
https://www.theguardian.com/cities/2015/may/05/amsterdam-bicycle-capital-world-transport-cycling-kindermoord

provided for each group, as well as case studies and assessments of strengths and weaknesses. These are summarised in Table 3.4.

Table 3.4 Summary of methods for estimating walking and cycling latent demand

Approach	Overview	Assessment
Pragmatic approaches	Where what goes in, the process it goes through, and what comes out are chosen considering what is at hand, what is needed, and what works for the given situation	• Tend to be quick and cost effective, employing data at hand, and adaptable to fit the purpose; generally seen as having inconsistent accuracy • Tend to be used for smaller scale and budget applications
Informed expert estimation: **As the basis of the forecast**	Subjective estimate based on available data and local context, combined with professional experience and judgement	• Potentially prone to subjectivity and bias • Potentially accurate or inaccurate depending on the skill and experience of the practitioner • Used to overcome data and knowledge limitations
Informed expert estimation: **To rationally adjust a forecast from another method**	Using judgement to modify or complement output from another method	
Informed expert estimation: **To make assumptions about components of a method or model**	Judgement applied to the use, processing, and interpretation of data or information within a latent demand estimation method	
Comparison approaches	Looking at walking and cycling levels, or changes in levels due to some interventions, in certain places, and using this information to estimate latent demand in other similar types of places	• Requires that walking and cycling case study data is readily available • Requires skill in assessing the transferability of findings from place to place
Sketch planning	Relatively coarse and generic formulas or factoring	• Quick and cost effective • Tend to be generic and coarse to an extent that they have lower accuracy
Demand typologies	Categorisation of a population to identify groups with latent demand for walking and cycling	• Useful for understanding demand and latent demand characteristics across a population
Stated preference based	Methods that are primarily based on stated preference data and techniques	• Useful for testing perceptions, and the potential behavioural response of those people with latent demand for walking and cycling, or to infrastructure that is new (ie, where there is no data on how it may be used) • Can be seen as unreliable and prone to bias • Best used in combination with other data (ie, revealed preference data)

Approach	Overview	Assessment
Revealed preference based	Methods that are primarily based on revealed preference data and techniques	• Tend to be seen as being more reliable than stated preference based methods • Have limitations when real choices are constrained, applied to latent demand, or something new
Traditional transport models	Conventional transport modelling processes are adapted to improve suitability for walking and cycling	• The accuracy of any model is dependent on the quality of data and the robustness of the parameters of the model • May not readily account for behavioural 'tipping points' or changes in system dynamics • Applications for cycling much more advanced than for walking • Capable of representing complex land-use and transport interactions and trends over time, and multimodal transport systems at a network level • Various enhancements possible to better represent walking and cycling behaviour • Data and technology intensive
Geospatial assessments	Data is processed and/or presented in a GIS	• Capable of integrating a wide range of complex geospatial information (including output from transport and other models) to form a comprehensive, multi-criteria assessment of walking and cycling demand • Data and technology intensive

4 Decision tree

The third objective of this research project was to employ the research findings to describe preferred approaches for different geographic scales and levels of network investment that could be adopted nationally in New Zealand for greater consistency in walking and cycling demand estimation. This section presents the decision tree, or framework, created to guide practitioners towards the most fit-for-purpose methods to estimate latent demand for walking and cycling. A key consideration in developing the decision tree was to ensure that the effort and cost of producing a forecast be in keeping with the scale of the project and its expected impact on walking and cycling travel (Department for Transport, 2018).

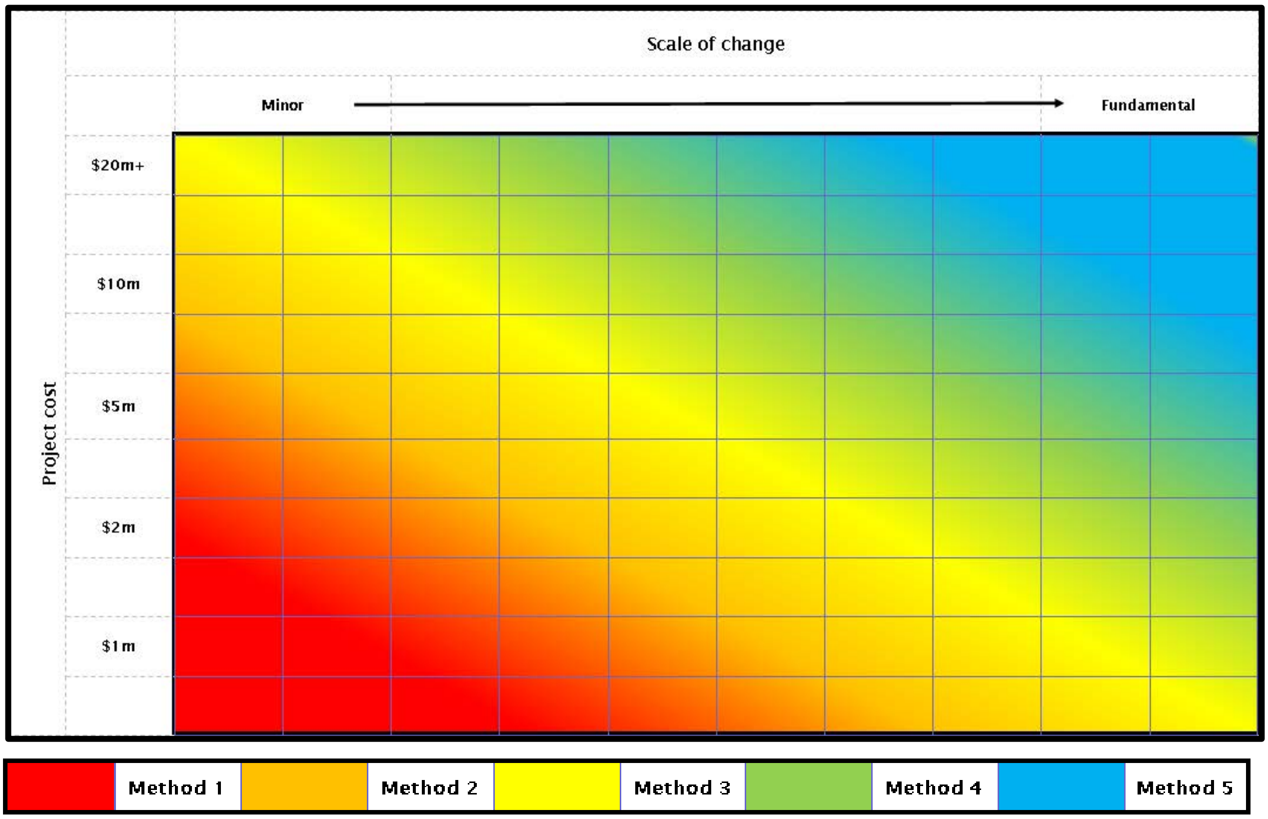
Table 4.1 provides the high-level decision tree to support the selection of a demand estimation approach for use in conjunction with the walking and cycling demand method selection matrix (Figure 4.1).

Table 4.1 Walking or cycling project demand estimation decision tree

<table>
<tr><th colspan="6">Walking or cycling project demand estimation decision tree</th></tr>
<tr><td>Step 1: Scale</td><td colspan="5">Determine the scale of the project: Is it specific to a corridor or key intersection, or is it a network-wide approach? This is an opportunity to review targets for the project (such as level of service or mode share targets).</td></tr>
<tr><td>Step 2: Cost</td><td colspan="5">Determine the broad project cost.</td></tr>
<tr><td rowspan="3">Step 3: Method</td><td colspan="5">Use the walking and cycling demand method selection matrix (Figure 4.1) to select the appropriate method for your project, applying professional discretion as required, based on the scale and cost from steps 1 and 2.
Note: If an established local demand method exists (such as a walking or cycling model), and is suitable for the project, consider using this.</td></tr>
<tr><td>Method 1: Sketch plan equation (cycling).
Informed expert estimation (walking).</td><td>Method 2: Sketch plan equation with informed expert calibration (cycling).
Informed expert estimation (walking).</td><td>Method 3: Comparison approach combined with an evaluation of level of service and potential use. Employ modifying factors based on the local context.</td><td>Method 4: Geospatial assessment combined with an evaluation of level of service and potential use. Employ modifying factors based on the local context.</td><td>Method 5: Transport model with locally specific data and factors.</td></tr>
<tr><td colspan="5">Review the appropriate methods.
(See also Chapter 3 for more detail on the approaches and data sources.)</td></tr>
<tr><td>Step 4: Structures</td><td colspan="5">Look at whether the locations include shared paths or structures (or other facilities that would be difficult or costly to widen).*
The risk associated with underestimating demand for these facilities is potentially greater than for other facility types, due to the longer lifespan and difficulty of widening structures, and the potential for user conflict on too-narrow shared paths.
Use professional judgement to determine if the forecast is at risk of underestimating demand for the project lifespan and adjust as appropriate.
* Examples of structures include bridge, bridge clip on, board walk, underpass/retaining structures, sea protection, rail crossing, bridge widening, or structure with significant cost and/or life (ie, greater than $30 million and/or significant life of 50 years plus).</td></tr>
</table>

Step 5: Growth	Is the project expected to provide a fundamental step-change in walking/cycling provision or outcomes? For example, a final link in an otherwise connected route, an iconic route with high recreational value, a substantial increase in the level of service of an arterial route. Use professional judgement to estimate growth potential over the next 10 years. A high growth would be 3% or greater per year. If high growth is anticipated, then consider using more robust forecasting methods or adjust demand forecast as appropriate.
Step 6: Modifying factors	Adjust the forecast based on additional modifying factors that may affect volume or type of use, using informed expert estimation, as appropriate for the local context, such as adjustment for tourist use, characteristics of the place or route, e-bike uptake, micro-mobilities, elderly or mobility device use. Consider complementing the assessment with stated preference data or methods collected from the local community (such as a survey of community preference, intention to use, or a demand typology segmentation; see sections 3.3.2 and 3.3.3).
Step 7: Peer review	Identify an appropriate reviewer and review process, ideally from an accredited list, if established (to promote consistency).

Figure 4.1 Walking and cycling demand method selection matrix



5 Walking and cycling demand case study database

5.1 Background

The first stage of this research identified the potential for development of a demand case study database. Such a database would provide a useful input for comparison-based demand forecasts and was also identified during the research primary data collection as a 'latent demand' for practitioners. Following a hold point in the research to consider the work to date, the steering group asked the research team to provide a proposal to outline the development of a walking and cycling demand case study database. This was developed and then further refined in response to feedback from the steering group.

5.2 Method

The database development included two main steps:

1. the development of database fields (to be presented in an Excel spreadsheet)
2. populating the database with an initial set of case studies.

5.3 Database fields

The database fields were based on the research findings to date, as well as the professional experience of the research team, and by the research steering group. It was designed to include the following indicators.

- Contextual factors
  - Location name and type of place/s (including for origin, route, destination; eg, suburban through arterial road to city centre)
  - Area-wide mode share for each mode for journey to work
- Facility factors (before and/or after)
  - Project name
  - Facility type
  - Facility scale and length
    - Area/complete route/section of route/spot improvement
  - Dates of key stages (before, during, and after completion)
- Facility and adjacent route (where available and relevant) demand (before and/or after, and/or ongoing)
  - Method and dates of measurements
- Latent demand forecast and method type
- Key contact information (organisation, role, person)

Practical points to note were as follows.

- While there is a desire to have standardised reporting outputs for comparison between cases, there will be very different reporting methods across cases.
- Some of the information can be represented and sourced most easily through a geospatial platform, particularly location of the initiatives and local contextual factors in the built environment.

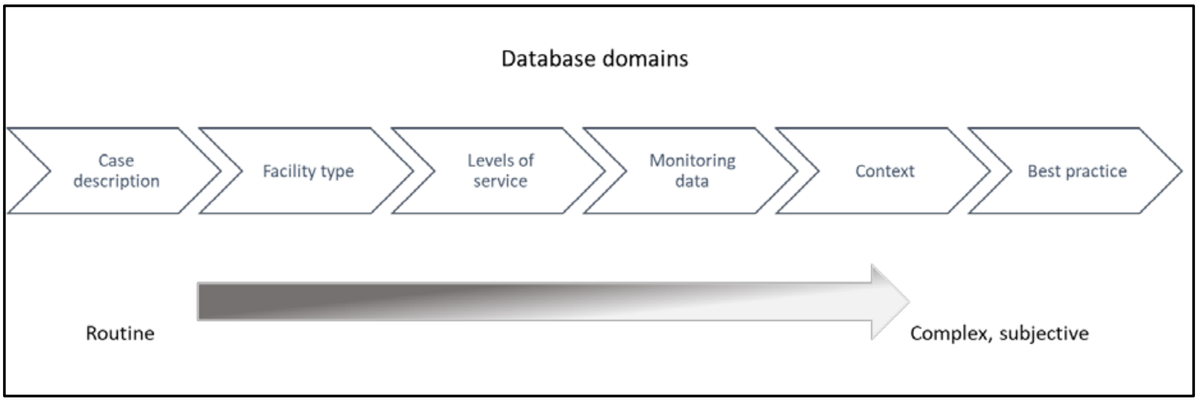
- While there are a lot of fields, not all cases will have data (eg, where no pre-intervention data was collected). Some cases will require follow up to determine whether more information could be gleaned through other means and the value of the additional effort.

5.3.1 Fields development

A hierarchy of information was developed to ensure adequate coverage of the primary topics: domains > indicators > variable input (eg, levels of service, count data) > variable output (derived standardised outputs where appropriate). The variables are a mix of quantitative and qualitative forms, including multi-choice, scales, ranking, and open field questions.

Six domains were identified (Figure 5.1). The order of domains in the database go from relatively simple, routine information (case description and facility type) to more complex and subjective information (describing the wider context, adherence to best practice). The order recognises that by working through the easy and useful information first, practitioners may better appreciate the value of sharing more sensitive information.

Figure 5.1 Database domain order



5.4 Database generation

Fields were trialled using five historical projects and by translating three of the cases in the Ngāūranga to Petone demand memo into the database. As a proof of concept, we trialled a simple Maptionnaire map-based survey tool to identify and capture spatial and other information on walking and cycling projects from practitioners in a way that could generate a database. Finding it was successful, we further developed the questionnaire to capture all fields.

Potential cases were identified through our professional experience and through the Maptionnaire trial. From these, a range of potential cases were selected to demonstrate the ease with which relevant information could be collected. The range included walking/cycling, utilitarian/recreation, existing/under construction or pending, and section/network.

Two approaches were used to populate the database with cases. The top-down approach identified a range of potential cases sourced from WSP networks. The Maptionnaire survey was used to elicit the desired data fields through participation in the survey through self-completion and/or as part of an interview.

The bottom-up approach harvested count data available from local authority and national cycleways as a starting point for populating cases. Cases with available data were selected to ensure coverage of high-profile examples (such as Lightpath), quick wins (where we are confident of good quality count and general information), and to get a range of case types.

Once count and other readily available data was entered into the database, supplementary information was sought through the Maptionnaire survey and/or interviews. Data gaps are highlighted as grey cells in the database, and indicate situations where data was not available, could not be located, or does not exist.

5.5 Results

- Pedestrian projects and information were relatively sparse. No projects were identified that were only for pedestrians. Pedestrian count data was available within some councils but does not appear to be tied to specific projects. Contextual information such as level of service and neighbourhood type were sourced manually by Google Street View and Maps.
- Access to information and data quality varied considerably across councils and organisations. The most accessible data was found in Christchurch City Council, where count data was online, with mapped paths and counter locations etc. Wellington City Council also had a good range of accessible data, though their counter locations did not appear to be quite as closely linked to facilities. In some cases, it was unclear whether data could be accessed only through a local authority or also sourced directly from Waka Kotahi.
- Although after-data was readily available online from several councils, before-data proved much more difficult to obtain. Most of the automatic counters at locations where facilities have been constructed were installed along the route either during or after construction. Contacting councils to request before-data for these facilities has so far not been very successful. In some cases, we were referred back to Waka Kotahi.
- Multiple approaches to sourcing information to populate case studies were required. They included harvesting from online sources, requesting directly from a local authority or other organisation, and primary data collection through interviews and/or surveying. Generally speaking, the more complex and subjective information required primary data collection. Level of service and project value information was generally available through project personnel rather than as part of online project profiles.
- Even for some relatively high-profile projects it was challenging to find detailed and useful information online. For some facilities, even locating the exact route proved difficult. Councils such as Christchurch and Wellington maintain interactive online maps of their facilities to aid discoverability, but others rely on PDF or image-based maps, which can be more cumbersome to use. Third-party mapping services like Google Maps did provide information on some facilities but not all. Often, the best places to look for information about a new facility were news articles and blogs.
- In some situations, finding the current status of a facility (ie, fully open, partly open, under construction, in planning, etc) was difficult. Some project pages did not appear to be readily updated with new information and it took a fair amount of investigation to determine its status.
- The amount of time and effort required to populate the database varied substantially from case to case, depending on how accessible the information was. Where information was highly accessible, these entries could be completed within several hours or less, but in other instances sourcing information required a more significant amount of time and effort.

5.6 Future database considerations

The walking and cycling demand database is likely to be most useful if it is regularly updated with new cases. Consideration should be given to how this may be best achieved, perhaps by incorporating it as a routine process. It is likely that the fields and format of the database will need to be revised, as a living document, based on feedback from stakeholders in order to maximise its usefulness. Potential fields that could be considered for future inclusion are a description or measure of relevant catchments for resident, working and studying populations, as well as some assessment of the quality of the facility (eg, via a level-of-service score). Knowing the difference in values between the previous state and the new/proposed state may inform understanding as to what effect on demand the new facility will have. The exercise of populating and developing the database may in turn lead to identifying opportunities for improved or new walking and cycling data collection.

The populated database is a stand-alone spreadsheet. A link to the file is provided in Appendix B.

6 Conclusion and recommendations

The past decade has seen substantial progress made to develop the range and quality of methods used to forecast latent demand for walking and cycling. It has also seen efforts being made to better incorporate insights from research into walking and cycling behaviour and behaviour change. As expected, this research found that methods to forecast demand for cycling were far more abundant and tended to be more advanced than those for walking. Additionally, the information available about the various methods, their application, and their evaluation is highly variable and inconsistent.

6.1.1 Recommendations

Based on the research findings, the following recommendations are made.

6.1.1.1 Data

- Efforts should be made to continue to improve the routine and equitable collection and sharing of quality walking and cycling count data across New Zealand, including establishing data standards and funding and contractual mechanisms to promote collection. This will aid:
  - understanding of the levels and characteristics of walking and cycling behaviour and the potential for change
  - in documenting the effect of the transport network and other changes on latent demand.
- Efforts should be made to install automatic bi-directional cycle and pedestrian counters at key sites along routes where a cycleway or walkway facility is planned or proposed.
  - This will allow high-quality before-data to be captured and compared against after-data once the facility has been opened. Right now, before and after counts (if done at all) are often done at different locations using different count methods, which makes comparison challenging and less accurate.
  - In addition to providing a comparison for a particular facility, this data can be used to help identify the potential latent demand for similar projects.
- Consider the value of addressing the limitations of revealed preference data for walking and cycling through regular collection and use of consistent stated preference data and methods.
- Consider the upkeep and development of the database of walking and cycling facilities and counts to inform comparison approaches to latent demand forecasts, help improve the accuracy of other methods, and improve our understanding of high-value facilities (see Chapter 5 for more detail).

6.1.1.2 Demand guidance

- Consider target setting leading the forecast: setting a strategic target based on goals such as mode share, level of service, amenity, equity, or safety, then using forecasts to prioritise facilities in reaching the target.
- Consider promotion and use of the decision-tree approach (outlined in Chapter 4) to support practitioners in selecting a robust demand forecast method.
- Consider updating the New Zealand cycling sketch plan procedure (SP11) so that it is more responsive to different infrastructure levels of service and perhaps environmental contexts.
- Ensure that transport modelling guidance in New Zealand is suitable for walking and cycling models.

- Consider pilot projects validating or adapting successfully tested open-source software tools, such as the Cycling Infrastructure Prioritisation Toolkit (CyIPT) and the complementary Propensity to Cycle Tool (PCT).

6.1.1.3 Advancing the state of practice

- Encourage the sharing of methods, strengths, weaknesses and assessments to improve the state of practice and sense of legitimacy in New Zealand.
  - Consider the implementation of an open peer-review system and the potential for accredited reviewers, where the reviewer and practitioner are able to engage in open conversation to discuss the latent demand approach taken and the resulting forecast, in order to improve consistency and learn and advance the state of practice.
  - Consider the potential for mentor–mentee relationships to advance learning among practitioners.
  - Consider training or workshop sessions led by various experts in demand forecast and data capture and analysis methods, and case studies.

6.1.1.4 Transparency and consistency

- Encourage demand forecasts to be produced with transparency around their assumptions, what they take into account (and what they do not), and their limitations.
- Consideration should be given to the effect of different assumptions on the resulting demand forecast.
- Effort should be made to ensure that consistent assumptions are made when comparing demand forecasts across projects.
- Background growth rates should be estimated to compare the investment to a without-case-reference scenario.
- Sensitivity tests should be used to evaluate the effect of uncertainty in walking and cycling demand forecasts on the case for the project.

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Appendix A: Stocktake survey

Demand forecasting methods for walking and cycling

1. Haere mai | Welcome

Thank you for choosing to participate in this short survey about your insights and experience with walking and cycling projects and/or demand forecasting methods.

Your response will contribute to a wider research project being undertaken by WSP Research for Waka Kotahi NZ Transport Agency aiming to provide evidence to improve the consistency and accuracy of walking and cycling demand forecasting in New Zealand. The results of this research will be publicly available for use by interested practitioners and policy makers.

We anticipate that the survey will take **about 5-10 minutes**.

We understand that aspects of some demand forecasting methods and projects may be propriety or commercially sensitive. In such cases, please feel free to respond with a level of detail appropriate to these circumstances.

1

Demand forecasting methods for walking and cycling

2. Feedback option: demand forecasting method(s)

1. Have you been involved in the development of a walking and/or cycling demand forecasting method or model?

- ◯ Yes
- ◯ No

2

Demand forecasting methods for walking and cycling

3. Feedback on the development of a walking/cycling infrastructure demand forecasting method.

Thinking about the **most relevant** (or most recent if you prefer) walking and/or cycling infrastructure demand forecasting method you have been involved in the development of:

2. Could you **tell us about** this demand forecasting method?

What is the name of this approach?

Who developed it? (e.g. key people, organisation)

Who owns it?

3. Which of the following best describes the **demand forecasting approach**? *Please select all that apply.*

- ☐ A sketch-plan method (*e.g. EEM SP11 or LTNZ Report 340*)
- ☐ A choice model (*e.g. route or mode choice models*)
- ☐ A GIS-based assessment
- ☐ A transport model-based assessment
- ☐ Other (please specify)

3

4. Which **travel modes** does (or can) this demand forecasting method apply to? *Please select all that apply.*

- ☐ Walking
- ☐ Cycling
- ☐ Electric-cycling
- ☐ Micro-mobilities (scooting, skating etc)
- ☐ Other (please specify)
- ☐ Electric micro-mobilities (e.g. e-scooters etc)
- ☐ Public transport
- ☐ Motor vehicle

5. If you are able to, could you please list the **types and sources of data** this method requires to produce demand forecasts? *For example:*

- current travel behaviour (e.g. manual/auto counts, NZ household travel survey, app-based heat maps)
- revealed and stated preferences, perceptions and attitudes (e.g. from literature or locally collected)
- socio-demographic (e.g. age, gender from census)
- land use
- levels of service, accessibility
- walking/cycling infrastructure/network, etc

4

6. Please **rate** this demand forecasting method(s) in terms of your perception of its:

	Low	Moderate	High	N/A or don't know
Cost ($)	○	○	○	○
Amount of time to develop	○	○	○	○
Amount of time to use	○	○	○	○
Data requirements	○	○	○	○
Expertise required	○	○	○	○
Technology	○	○	○	○
Accuracy	○	○	○	○
Fit for purpose	○	○	○	○
Transferability	○	○	○	○

7. If your demand forecasting method has been **applied to project(s) or network(s)**, could you please name these below and indicate whether before/after use data has been captured?

8. Do you have a report or other information about this demand forecasting approach or its use that you can share with us? *If so, please upload here:*

Choose File   No file chosen

9. Please share any other comments you have below:

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Demand forecasting methods for walking and cycling
4. Any other methods?

10. Have you been involved in the development of any other walking and/or cycling infrastructure demand forecasting methods?

- ◯ Yes
- ◯ No

6

Demand forecasting methods for walking and cycling

5. Other walking and/or cycling infrastructure demand forecasting methods

11. Please can you briefly list the other walking and/or cycling infrastructure demand forecasting method(s) you have been involved with?

We may like to ask you about these. If you are okay with us getting touch, please provide your contact details later in the survey.

7

Demand forecasting methods for walking and cycling

6. Feedback option: walking and/or cycling infrastructure project

12. Would you like to give feedback on a specific walking and/or cycling infrastructure project you have worked on (which may or may not have demand forecasts and before/after counts)?

◯ Yes

◯ No

8

Demand forecasting methods for walking and cycling

7. Feedback on a walking and/or cycling project: background information

13. Thinking about the most relevant* walking and/or cycling infrastructure project you have been involved in, **was this project primarily...**

**Note: if you have a lot of projects to choose from, we are particularly interested in ones that have before/after count data.*

- ○ ... a walking project?
- ○ ... a cycling project?
- ○ ... both a walking and cycling project?
- ○ Other (please specify)

14. If you are able to, could you please tell us a bit more **about this project...**

What is the name of the project?

What is the location of the project?

What year was the project completed? *Please state anticipated completion if ongoing*

Can you briefly describe the infrastructure created? (e.g. type, length etc)

9

15. What was the **scale** of this project? *Please select all that apply.*

- [ ] An area-wide treatment
- [ ] A section of a route - route remains incomplete
- [ ] A section of a route - completed a missing link
- [ ] A spot improvement (e.g. pinch point or intersection)
- [ ] A complete route
- [ ] Other/comments:

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Demand forecasting methods for walking and cycling

8. Feedback on a walking and/or cycling infrastructure project: demand forecasts

{{ Q14.R1 }}

16. Were **demand forecasts produced** for this walking and/or cycling project?

- ◯ Yes
- ◯ No, but demand forecasts would have been useful
- ◯ No, and I don't think demand forecasts would have been useful

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Demand forecasting methods for walking and cycling

9. Feedback on a walking and/or cycling infrastructure project with demand forecasts

{{ Q14.R1 }}

17. For what **purpose** were demand forecasts produced for this project? *Please select all that apply*

- ☐ Network/route planning (e.g comparing and selecting route/s and/or infrastructure type/s)
- ☐ To evaluate the need for investment (e.g. economic costs/benefits, social, equity, or amenity evaluation etc)
- ☐ To allow for assessment of the success of the project (e.g. post-evaluation, to share stories etc)
- ☐ Other (please specify)

18. For what **scale** were the **demand estimates** produced for this project? *Please select all that apply.*

- ☐ Future user numbers at a particular site
- ☐ Future user numbers across a network
- ☐ Future user numbers along a particular route
- ☐ Other/comments:

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19. Which of the following best describes the **demand forecasting approach** used for this project? *Please select all that apply.*

- ☐ Estimates based on professional experience and judgement
- ☐ Comparison of proposed infrastructure with similar existing infrastructure built elsewhere (*e.g. benchmarking, ex-post evaluation*)
- ☐ A sketch-plan method (*e.g. EEM SP11 or LTNZ Report 340*)
- ☐ A choice model (*e.g. route or mode choice models*)
- ☐ A GIS-based assessment
- ☐ A transport model-based assessment
- ☐ A pilot project in-situ that monitored uptake to assess demand (e.g. a pop-up pedestrian space or cycle lane)
- ☐ Other (please specify)

20. Could you **tell us a bit more** about the demand forecasting approach used for this project? (*If you are not able to, or this does not apply, please skip to the next question*).

What is the name of this approach?

Who developed it? (e.g. people, organisation)

Who owns it?

13

21. If you are able to, could you please list the **types and sources of data** this method used to produce the demand forecasts? For example:

- current travel behaviour (e.g. manual/auto counts, NZ household travel survey, app-based heat maps)
- revealed and stated preferences, perceptions and attitudes (e.g. from literature or locally collected)
- socio-demographic (e.g. age, gender from census)
- land use
- levels of service, accessibility
- walking/cycling infrastructure/network, etc

22. Please **rate** the demand forecasting method(s) used for this project in terms of your perception of its:

	Low	Moderate	High	N/A or don't know
Cost ($)	○	○	○	○
Amount of time to use	○	○	○	○
Data requirements	○	○	○	○
Expertise required	○	○	○	○
Technology	○	○	○	○
Accuracy	○	○	○	○
Fit for purpose	○	○	○	○
Transferability	○	○	○	○

23. Do you have a report or file with information about the demand forecasting approach used for this project that you can share with us? *If so, please upload here:*

Choose File No file chosen

24. Please share any other comments you have below:

14

15

Demand forecasting methods for walking and cycling

10. Feedback on a walking and/or cycling infrastructure project: no forecasts, would have been useful

{{ Q14.R1 }}

25. Could you please tell us about why demand forecasts were not able to be produced for this project, and how they may have been useful?

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Demand forecasting methods for walking and cycling

11. Feedback on a walking/cycling infrastructure project: no forecasts, would not have been useful

{{ Q14.R1 }}

26. Could you please tell us about why you think demand forecasts would not have been useful for this project?

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Demand forecasting methods for walking and cycling

12. Feedback on a walking and/or cycling infrastructure project: user counts

{{ Q14.R1 }}

27. Has this walking and/or cycling project collected before AND/OR after user counts?

- ◯ Yes, before AND after
- ◯ Yes, before counts only
- ◯ Yes, after counts only
- ◯ No

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Demand forecasting methods for walking and cycling

13. Feedback on a walking and/or cycling infrastructure project with user counts

{{ Q14.R1 }}

One of the possible outcomes of this project is a database of before and after count data to help with future demand estimates.

28. Could you please provide some information about this count data.

Who did you count, what with, and how? ***(e.g. manual or automated; short-term or continuous counts; number of count locations; people walking and/or cycling, etc)***

29. Are you able to make the before / after count data available for this project?

○ No

○ If yes, please can we have your contact details?

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Demand forecasting methods for walking and cycling

14. Any other walking and/or cycling projects?

30. Have you been involved in any other walking and/or cycling infrastructure projects (especially if demand forecasts were produced or before/after counts)?

- ◯ Yes
- ◯ No

20

Demand forecasting methods for walking and cycling

15. Other walking and/or cycling infrastructure projects

31. Please can you briefly list the other walking and/or cycling infrastructure projects you have been involved with (and please indicate if demand forecasts or before/after counts were produced)?

We may like to ask you about these. If you are okay with us getting touch, please provide your contact details later in the survey.

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Demand forecasting methods for walking and cycling

16. Insights into walking and/or cycling latent demand or forecasting methods

32. If you would like to, please share any insights you have into walking and/or cycling latent demand or forecasting methods here:

For example, you may want to point to gaps in knowledge or practice, or ideas you have on how demand forecasting could be improved.

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Demand forecasting methods for walking and cycling

17. About you

33. What sector do you work in?

- ◯ Consulting
- ◯ Local government
- ◯ Central government
- ◯ Academic
- ◯ Other (please specify)

34. Do you mind if we get in touch?

We will be following up some survey responses with short phone or in-person interviews. If you are available to participate in this, please provide your contact details here:

35. Can you think of anyone else who may want to be offered the opportunity to contribute to this research project?

Please feel free to forward them this survey, or if you would like us to, please enter their contact information below:

36. Please share any final thoughts or comments here:

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Demand forecasting methods for walking and cycling

18. End of survey

Thank you

For your time and participation in this survey.
Your response is appreciated.

If you would like to contact the research team directly, for any reason, please email or call Jean:

jean.beetham@wsp.com | 027 314 2380

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Appendix B: Case study database

The spreadsheet is available at www.nzta.govt.nz/resources/research/reports/676