# Pedestrian Demand Forecasting Methods Guidance: Research Report

Prepared for Department of Transport and Main Roads

CDM RESEARCH

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# Executive Summary

This research report reviews pedestrian demand forecasting guidance and current practices. Specifically, the scope of this research report is to:

1. Review Australian and international **guidance** on pedestrian demand forecasting.
2. Review **data collection** techniques for pedestrians and how they may be used to improve demand forecasting and level of service measures.
3. Identify pedestrian demand forecasting **methods** and their applicability to Queensland.
4. Identify and review **case studies** where pedestrian demand forecasting has, or has not, been used in infrastructure projects and the benefits that could have accrued from doing so.

The main finding from this review is that an absence of data on pedestrian demand is severely limiting progress towards developing robust, practical demand forecasting tools. Moreover, where data is being collected it is rarely made available to practitioners in a manner that is suitable for use in demand forecasting. Until these shortcomings are addressed it will be difficult to make progress towards practical demand forecasting procedures in Queensland.

Other specific findings from this review are:

- **Guidance:**
    - Most pedestrian forecasting guidance in Australasia is based on a study commissioned by the US Federal Highways Administration in 1999. The Australasian guidance includes bicycle facility forecasting by Austroads in 2001, by the New Zealand Transport Agency in 2009 and in the Australian Transport Assessment and Planning Guidelines (Part M4, Chapter 4) in 2016. While the advice in these guides is reasonable it does not significantly improve upon the advice provided in the original US guidance.
    - The guidance identifies general methods and, with one exception described below, describes them only at a very high level; practitioners would need to have a deal of understanding of the technical basis of these methods in order to implement them in a practical context.
    - The US National Cooperative Highway Research Program commissioned a research report published in 2014 that developed sophisticated pedestrian models using a discrete choice framework. These models are intended to complement strategic transport models. This guidance differs from the other guidance identified above by being very thorough but also very complex for the non-expert practitioner to implement.
    - There have not been significant developments in forecasting methods over the past 10 – 20 years that would make the existing guidance out-of-date or incomplete.

- **Data collection:**
    - The quantity and quality of pedestrian data collected in Queensland is inadequate to support the development of high-quality demand forecasting procedures.
    - Where data, usually counts, are collected the data is not stored in a consistent manner nor is it readily available for practitioners to use to estimate demand from existing projects or to develop forecasting models.
    - Much greater emphasis on long-term, high quality pedestrian counts data collection using automatic counts is required to improve the quality of the data collection, as is the use of intercept surveys as part of the evaluation of pedestrian infrastructure projects to identify latent demand.
    - Given the limited data available, and limited funding available to undertake dedicated pedestrian data collection, a pragmatic approach is warranted to make the most of what is available. In this regard an investigation into the use of existing data sources that are not otherwise used such as STREAMS cycle analyser data for pedestrian operated signals would be warranted.
    - While there are limitations in walking data collection within major travel surveys such as the Queensland Travel Survey, specifically with respect to underreporting of short walks to and from cars parked in public spaces, these are unlikely to present a significant limitation to using this data.
- **Methods:**
    - Relatively simple forecasting methods will be the most practical and consistent with the scale of investment in walking.
    - The simplest approach is a *comparative analysis* – that is, observing demand at existing, similar sites and inferring the likely demand for a proposed project. This method would ideally use a repository of counts.
    - Once there is a sufficient sample of observed counts it will be possible to use *direct demand models*. These are equations that link explanatory variables related to land use (e.g. population, employment and proximity to schools) and transport infrastructure (e.g. presence and quality of footpaths, proximity to public transport) to pedestrian demand. To use either method in Queensland will require the collation of existing data (comparative analysis) followed by the estimation of the models.
    - More behaviourally robust, but technically complex, discrete choice models and strategic transport models are unlikely to be practical for anything but the largest pedestrian projects such as major bridges or tunnels. Further investigation of these approaches for development in guidance is unlikely to be warranted as the implementation of these methods will inevitably remain within the remit of transport modelling specialists.

# 1 Introduction

## 1.1 Background

The Queensland Government released the *Queensland Walking Strategy: 2019-2029* (TMR 2019b) in 2019. The strategy has the objective of more walking more often by ensuring communities are planned to make walking enjoyable and convenient. The strategy is supported by the *Action Plan for Walking: 2019 -2021* which lists as action 1.11 to:

> *Develop and publish detailed Queensland supplements to Austroads guidelines including guidance on pedestrian wayfinding,* ***modelling****, safety at slip lanes and roundabouts, priority crossing treatment options, and coordinating traffic signals for pedestrian "green wave" in high use areas.*
>
> ((TMR 2019a), p. 8)

The present work is a response to this modelling requirement, and specifically modelling as it relates to demand forecasting. Other actions within the action plan would also be expected to leverage off guidance on demand forecasting, including those that refer to improved walkability design guidance, pilot programs and the development of a business case for investment in walking.

The present report is the first deliverable towards this guidance. This report is not intended to be guidance in itself but rather aims to review current practices in pedestrian demand forecasting so as to identify shortcomings that may be addressed in the subsequent guidance. Specifically, this report addresses the first four tasks in the project scope (Table 1.1).

- **Table 1.1: Project stages**

| Task | | Scope |
|---|---|---|
| 1 | Literature review of current Australian and international best practice guidance | This document |
| 2 | Identify and review case studies from Australia and overseas | This document |
| 3 | Review data collection methods | This document |
| 4 | Prepare a research report on the above three tasks | This document |
| 5 | Prepare technical guidance | Guidance document |

## 1.2 Purpose

The ultimate purpose of this study will be to offer practical guidance on pedestrian demand forecasting to practitioners including local government officers and TMR staff who do not necessarily have transport modelling expertise. The purpose of the present report is not to prepare the guidance itself but rather to review existing guidance and methods of pedestrian demand forecasting to establish what can best be achieved in Queensland.

## 1.3 Scope

This research is focussed on forecasting methods that can assist in justifying and prioritising pedestrian infrastructure projects as well as providing inputs to cost-benefit and level of service analysis by estimating the number of pedestrians that will use a project – that is, demand.

As well as considering demand itself there will often be the need to estimate from *where* this additional demand may arise. For example, for a cost-benefit analysis it will be necessary to understand whether there has been any mode shift from car or public transport to walking as this will affect benefit streams such as congestion and crowding, emissions and health. Moreover, many pedestrian projects are likely to encourage all-new recreation walking trips which would not otherwise have occurred. Again, these will offer health benefits to these individuals (assuming walking is not a substitute for other physical activity) but will not otherwise benefit the transport system. This segmentation of demand is referred to as diversion within this report.

## 1.4 Definitions

This report refers to *forecasts* and *models*. A model in this context is a mathematical representation of transport demand that provides a demand *forecast* as an output given a set of input assumptions. However, a forecast does *not* require a model. Instead, professional judgement, perhaps based on data obtained from similar projects elsewhere, may provide a forecast that is as robust as a sophisticated and complex model. While models in complex situations can provide reliable forecasts they invariably involve a large number of assumptions, not all of which may be readily apparent to a user or reviewer. Moreover, models will use equations estimated from real-world data which invariably is incomplete and based on data that is incomplete or biased. Instead, some form of professional judgement, particularly where informed by experience on similar projects elsewhere, will be prudent given limitations of time, cost and technical expertise.

## 1.5 Limitations

This report does not consider modelling of crowd dynamics, including situations such as emergency access and egress from train stations and sport stadiums or pedestrian movements around intersections or in public spaces. This category is sometimes referred to as pedestrian simulation[1]. There is an extensive literature on this meso- and microscopic simulation of pedestrian movement but have as inputs the pedestrian demand assumptions. As such, the present research is concerned with the step *prior* to pedestrian simulation.

There is a relatively extensive list of studies that have identified walking *potential* or *walkability* using socio-economic and land use indicators at the regional scale. While useful as indicators of walking potential these approaches do not provide direct insight into the likely pedestrian *demand* on specific infrastructure. Instead, they can provide only an indication that there may be greater latent demand in one area than another. They are

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[1] Among the guidance on developing pedestrian simulation models is VicRoads (2019).

excluded from this review, except for limited instances where such methods have been used to try to extrapolate from *potential* to *demand*.

## 1.6 Determinants of walking demand

Walking demand will be affected by an array of factors, including:

- **Link quality:** the existence and quality of footpaths, traffic volumes, path width, slope and crossfall, shading, trees, seating and active street frontages among many factors
- **Network connectivity:** the permeability of the walking network (e.g. footpaths between buildings to allow for shortcuts) and presence of crossings (both at-grade and separated) over roadways and natural features such as rivers
- **Population characteristics:** gender and age, household structure, employment status and car ownership
- **Attractiveness of competing modes:** ease of driving and other modes of transport, availability of public transport (both as a competitor to walking for short trips and, when chained with walking, as a competitor to driving)
- **Land use:** population density and mixed uses to create walkable distances between trip generators and attractors
- **Climate/weather**.

These factors are far more extensive and complex than for motorised travel; in the latter the climate and weather are largely irrelevant, link quality is largely a matter of travel time and the networks tend to be much coarser than for walking. A robust walking demand forecast would need to be sensitive to these issues.

## 1.7 Why demand forecasting?

Demand forecasting for pedestrian infrastructure projects can assist in:

1. **Increasing the “visibility” of walking in transport investment decisions:** assist in justifying the need for walking provision, be it along transport corridors or as part of new developments – this is sometimes referred to as “if it’s not counted it doesn’t count”.
2. **Screening:** identifying prospective projects that have merit and are worthy of further consideration.
3. **Prioritisation:** allocation of scarce resources to those projects of highest merit first.
4. **Sizing:** determining facility dimensions, particularly widths, such that the facility can accommodate demand both on opening and over the projected economic life of the facility, recognising that it is almost invariably cheaper to build an asset to accommodate its longer term demand at the outset.

The screening and prioritisation process will often be part of the business case development and may include cost-benefit analysis, for which demand forecasts are a key input.

# 2 Guidance

## 2.1 Overview

The relevant guidance with respect to pedestrian demand forecasting in Australia and other English-speaking countries is reviewed in this section. A key finding from this review is that the three guidance documents identified in Australasia of most relevance (Austroads 2001; TIC 2016; NZTA 2009) are based almost entirely on an American review (FHWA 1999). Moreover, with the exception of one guidance document (Kuzmyak et al. 2014) the guidance is very general in nature and unlikely to be readily implementable by the non-specialist practitioner.

## 2.2 Pedestrian-specific guidance

### 2.2.1 Australian Transport Assessment and Planning

There is no pedestrian-specific demand forecasting guidance in Australia. There is however guidance that considers pedestrians and bicycle riders together. Among the most recent of these guides is the Australian Transport Assessment and Planning (ATAP) guidance on active travel (TIC 2016). This guide refers to five methods:

1. **Comparison studies:** use observed demand data from a similar, comparable project that already exists.
2. **Aggregate behaviour:** develop mathematical relationships between predictors such as population, demographics, land use and car ownership to overall walking demand at a local level (as opposed to individuals, as per discrete choice models below).
3. **Sketch planning:** estimate demand using simple calculations or rules of thumb about trip lengths, mode share and other relevant factors.
4. **Discrete choice models:** develop mathematical relationships between predictors such as population, demographics, land use and car ownership to overall walking demand at an individual level.
5. **Travel demand models:** traditional 4-step or activity-based models that incorporate trip generation, distribution, mode choice and assignment (route choice).

The discussion in the ATAP guidance is based on the review of FHWA (1999). The ATAP guidance suggests that the appropriate method will depend on the scale of the project:

> *For small scale initiatives with limited impact (such as a pedestrian refuge island or path widening), the comparative study might be the most appropriate approach to forecasting/modelling. A medium sized initiative (such as sizeable extensions to a cycle network or construction of an off-road shared path) might use the sketch planning method or a discrete choice model. A fully specified four-step network based model would only be justifiable for a major infrastructure initiative (such as a bridge over a river connecting with large residential or working populations).*

*((*TIC 2016) *p. 24)*

While not stated explicitly, these recommendations are presumably based on a recognition that smaller projects are unlikely to justify the time and cost of sophisticated methods.

### 2.2.2 Austroads Forecasting Demand for Bicycle Facilities

Many of the issues relevant to pedestrian demand forecasting are identical to bicycle demand forecasting. Austroads (2001) prepared guidance for bicycle forecasting which recommends essentially the same approaches as originally described in FHWA (1999), specifically:

- Aggregate behaviour
- Maximal share models
- Sketch planning, and
- Travel demand models.

"Maximal share models" in this reference refers to approaches that estimate the possible latent demand given population and land use characteristics, sometimes also called market analysis or demand potential (FHWA 1999). A recent Australian example of this type of study for cycling is near-market research undertaken for the City of Melbourne (CDM Research and ASDF Research 2017). These methods do not estimate the demand explicitly, but rather are indicators of demand potential.

### 2.2.3 NZTA Pedestrian Planning and Design Guide

One of the few design guides specifically devoted to pedestrian planning is the NZTA Pedestrian Planning and Design Guide (NZTA 2009). This guidance recognises that there is no robust way of forecasting pedestrian demand but does identify a number of options which again are based on FHWA (1999). These methods are summarised in Figure 3.4. The categorisation is somewhat arbitrary; for example, a "travel model" will almost invariably incorporate discrete choice modelling. Furthermore, the advice in the NZTA guidance and indeed the other guidance referred to in this section, is very high level and does not provide prescriptive guidance for a non-expert to implement the methods.

- **Table 2.1: Pedestrian demand forecasting methods as described by NZTA (2009) and derived from FHWA (1999)**

| Method | Description | Comment |
|---|---|---|
| Similar conditions study (comparisons study) | Conduct surveys before- and after an intervention and use this information to extrapolate to other prospective sites | Pragmatic approach that is simple and cost-effective to implement. However, requires a commitment to undertake the requisite data collection and ensure this data is available to practitioners. Context will be important such that the most sites available the better. |
| Aggregate behaviour | Fit equations to known pedestrian activity based on population (gender, age, employment status etc.) and infrastructure characteristics (age, employment status etc.) and then apply these equations to estimate demand at other locations. | Can use census data for universal coverage, but there may be no or poor pedestrian counts. Model fit can be poor such that predictive accuracy can be limited. |
| Sketch plan | Simple calculations based on rules-of-thumb about trip lengths, mode shares and other aspects of travel behaviour. | Vary widely depending on the project and data availability but usually a pragmatic way to proceed in the absence of time/cost to develop more sophisticated methods. |
| Discrete choice | Predictions of individual propensity to walk, and route choices, as a function of person and infrastructure characteristics. | Data intensive and requires technical expertise. Requires detailed network coding of pedestrian infrastructure. Has the advantage of providing sensitivity (elasticity) to infrastructure changes, hence facilitating demand forecasting for scenario testing. |
| Travel models | Fully developed travel model, either 4-step or activity-based, | Data intensive and requires technical expertise. Requires |

| Method | Description | Comment |
|---|---|---|
| | incorporating trip generation, distribution, mode choice and route choice. | detailed network coding of pedestrian infrastructure. Has the advantage of providing sensitivity (elasticity) to infrastructure changes, hence facilitating demand forecasting for scenario testing. |

An additional approach mentioned in FHWA (1999) but not in the summary in NZTA (2009) is the use of surveys of local travellers to understand their likelihood of using a facility. There are several types of surveys that can be used of varying complexity, from simple polling to stated intentions and stated preference surveys which seek to quantity the relative attributes of facilities. While there is an inherent risk in survey methods that respondents will overstate their willingness to use a new facility these methods do offer the opportunity to identify the attributes which may make the facility most attractive.

### 2.2.4 Austroads Pedestrian Crossing Facility Selection Tool

Austroads sponsored the development of a pedestrian crossing facility selection tool (Austroads 2015) that has three pedestrian demand inputs, for which limited advice on their measurement or estimation is provided (Austroads 2018):

> **Peak sensitive pedestrian volume:** the number of sensitive pedestrians using the facility in peak pedestrian hour [Average value from five surveyed pedestrian peak periods. Sensitive pedestrians include elderly, vision and mobility impaired, and pedestrians under 12 years of age]
>
> **Peak non-sensitive pedestrian volume:** The number of non-sensitive pedestrians using the facility in peak pedestrian demand hour [Average value from five surveyed pedestrian peak periods]
>
> **Estimated daily pedestrian volume:** Typical daily pedestrian volume including sensitive and non-sensitive users [Should be delivered from pedestrian surveys]

The guidance does not explicitly state whether these volumes are before- or after installation of a crossing treatment. However, the accompanying economic evaluation assumes no change in crossing demand because of the treatment. Moreover, the distance over which the pre-treatment counts should be obtained (in the absence of any facility) are not stated[2]. Given the assumption of static pedestrian demand no pedestrian demand forecasts are required in this approach, but it will tend to produce very conservative results.

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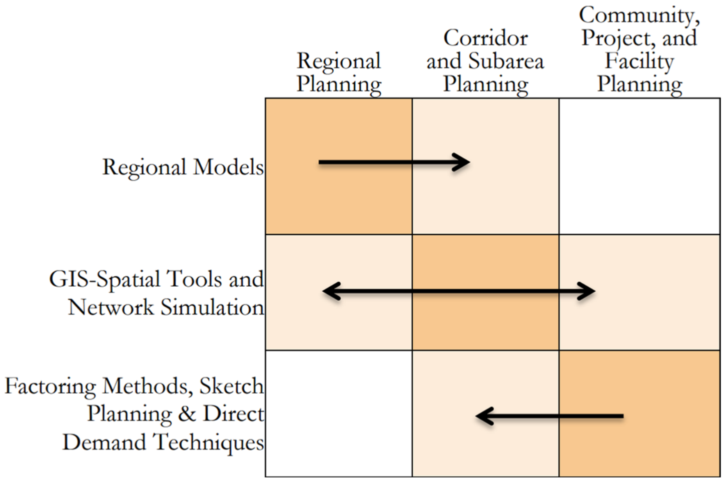
[2] Even if there is some form of existing crossing there will be some level of informal pedestrian crossing activity. Whether this informal activity should be counted within, say, 20 m, 50 m or 200 m is not stated.

### 2.2.5 NCHRP Estimating Bicycle and Walking for Planning and Project Development

Contrasting with the high level guidance reviewed above, the guidance developed in the USA by Kuzmyak et al. (2014) is extremely detailed and sophisticated. The guidance focuses on discrete choice models for implementation in or alongside strategic travel demand models. Recognising the technical complexity of the models, the authors provide spreadsheets and extensive documentation for the practitioner to implement the methods. However, despite the extensive support the technical sophistication of the methods is likely to limit their use to transport modelling specialists given the limited data availability and technical knowledge required in their application. Moreover, the models are estimated off travel data for Seattle and Washington DC which limits their transferability to an Australian context. Nonetheless, the methodology developed by Kuzmyak et al. represents current best practice for incorporating pedestrians into strategic travel models.

Aoun et al. (2015) provided a simplified summary of the NCHRP report, focussing on the less technically onerous methods such as sketch planning, direct demand and spatial analysis. They also suggested a link between the methods and spatial scale, where the simpler methods apply most readily to local projects (Figure 2.1).



- **Figure 2.1: Geographic scale of methods (Aoun et al. 2015)**

## 2.3 General guidance

Within the Austroads guides there is no explicit reference to pedestrian demand forecasting although there is some limited guidance on pedestrian counting and surveys (Austroads 2017). Beyond the Austroads guides many Australian states have their own transport modelling guidance. Most of this guidance refers to pedestrians only with respect to pedestrian simulation or insofar as they influence motor vehicle movements at traffic signals (VicRoads 2019; RMS 2013b). At the national level Infrastructure Australia has commissioned extensive strategic modelling for the purposes of forecasting urban congestion and crowding but these models again do not explicitly consider pedestrians (Infrastructure Australia 2019). Moreover, the discussion within this report on future modelling methods do not identify walking as an issue for consideration. Interestingly, even modelling guidance that applies specifically to activity centres do not provide guidance on forecasting pedestrian demand and indeed only refer to pedestrians insofar as they will affect traffic signal cycle times and hence motor vehicle delay (WA Department of Transport 2016).

Internationally the UK Transport Appraisal Guidance offers limited advice on modelling pedestrian demand, and generally advices that walking costs can be linearly dependent on distance using an average speed of 4 km/h (Sect. 4.7.8, p. 31 TAG Unit M2) (UK Department of Transport 2019). The modelling guidance does not however explicitly refer to pedestrian demand forecasting; the emphasis instead is on motor vehicle and public transport demand for strategic transport models.

# 3 Data Collection

## 3.1 Introduction

Pedestrian demand forecasting, as for any mode, is dependent on having access to good data. At a minimum the following is highly desirable:

- existing pedestrian movements in the project area,
- forecast population, employment and education trips in the project area that are unrelated to the project itself (e.g. due to natural growth, committed development or committed infrastructure such as new public transport connections), and
- sensitivity of the target market to improved walking infrastructure.

Pedestrian counts and surveys are fundamental requirements but are often obtained only on an *ad hoc* basis or as part of larger data collection activities. Among the most useful data collection can be from before- and after-monitoring of new infrastructure so as to obtain insight into the effect infrastructure has on walking activity.

The majority of pedestrian data is obtained as part of larger multimodal data collection activities such as the census (ABS 2017) and household travel surveys such as the Queensland Travel Survey (QTS). These data sources are very useful insofar as they obtain walking data in a manner consistent with other modes, have been running for many years and are widely recognised as credible. However, they both have clear limitations:

- the census reports data only on journeys to work on a Tuesday in August (and thus can be sensitive to weather), and
- the QTS provides data on all walking purposes but the sample size is limited, particularly when examining local areas.

## 3.2 Standardisation

There are few standards for walking data collection. The International Walk Data Standard (Sauter et al. 2016) was established as a means of harmonising macro-level indicators of walking to facilitate comparisons across regions or over time within one region. The standard uses five key performance indicators:

1. Share of people who have made at least one walking trip stage (stop) on the survey day
2. Average number of daily walking trips per person
3. Average daily travel time walked per person
4. Average daily distance walked per person
5. Mode share

The standard uses three levels: minimal, standard and elaborate defined by the period over which data is collected. At the minimal level the indicators would be measured on an average working weekday, increasing to a full week for the standard level and full year for the elaborate level. Even at the minimal level the benchmark would require an extensive data collection effort and would be beset by definitional and reporting issues such as:

- Defining when a walk becomes a walk – e.g. whether walks within a home, or to a car parked in a garage or on the street is a walking stage.
- Defining walking trips and stages – e.g. is a walk from home to a café, then to a supermarket, then to a school to escort a child to home count as one trip or four?
- Self-reporting limitations of time and distance, especially when using retrospective surveys (i.e. respondents will both forget trips and their duration, and even when they do recall will only approximate their duration and distance).

Moreover, detecting changes over time (i.e. longitudinally) or across regions (i.e. cross-sectionally) can be very difficult when these changes are small. In practice this is likely to be the case, especially for longitudinal studies where the intervention may be localised and the impact on walking activity modest even at a local level. The sample sizes required to detect changes in these indicators are then likely to be quite large.

## 3.3 Counts

Pedestrian counts are fundamental to demand forecasting because they:

1. provide a means of sense-checking or guesstimating demand for a new facility based on existing similar facilities, and
2. provide essential data to estimate and calibrate demand models.

Pedestrian counts are usually based on short period counts obtained manually from video cameras extending over a few hours to a day and rarely longer than a week. These counts are then used to infer demand on a “typical” or “average” day. While generally cost-effective, this approach can be sensitive to seasonal- and weather-related variations *and* to the natural day-to-day fluctuations which will occur such that this extrapolation of a short-period count to an “average” can be unreliable, as will be discussed in Section 3.3.2.

### 3.3.1 Sampling

Manual counting can quickly become laborious at locations with very high pedestrian volumes. In these cases, it is common to sample shorter time periods and expand these counts. For example, counts could be taken only for the first 5 minutes in every hour and expanded by the ratio 60/5 to an hourly estimate. Transport for London (2007) published guidance that suggest two one-hour periods (10 – 11 am, 4 – 5 pm) on one day can provide weekday count accuracy within a margin of error of 25% and 90% confidence interval. This error can reduce to 5% if the first 5-minutes is counted on one weekday between 7 am and 10 pm. Full 7 am – 10 pm counts over three weekdays may provide margins of error of 4% with a higher 95% confidence interval. These estimates were based on urban sites with daily demand above 1,000 pedestrians and a high proportion of transport walking activity; locations with high discretionary (recreational) walking activity would likely exhibit much greater variation than stated in this guidance.

### 3.3.2 Interday variability

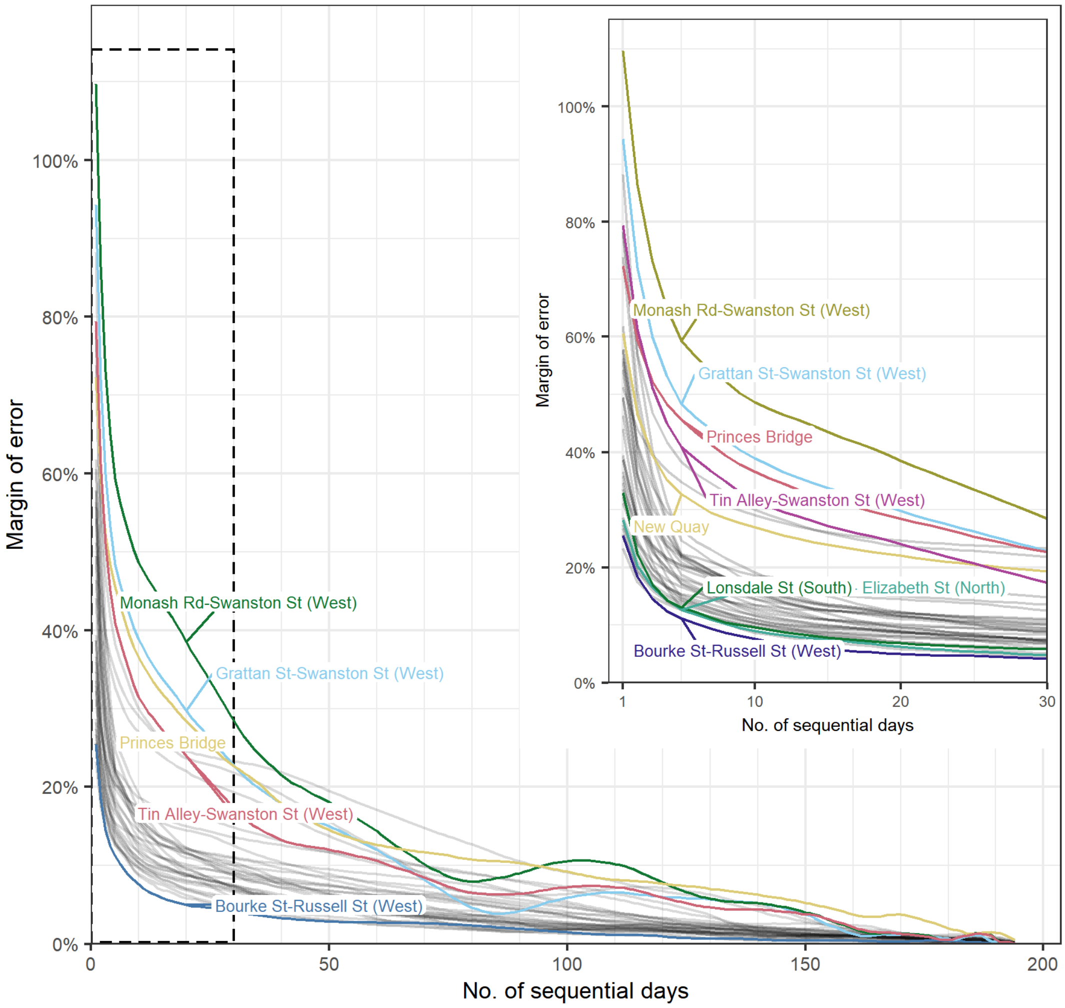
Forecasts are invariably made on the basis of an *average* day, usually a weekday but may also be an *average* weekend day. However, counting on a single non-holiday weekday relies to a large extent on luck to ensure this day truly is *average*. For example, based on automatic pedestrian counts from the City of Melbourne sampling one 24-hour non-holiday weekday the median relative standard deviation would be 44%, with a range from 25% to 103% across 38 inner city footpaths (Figure 3.1). In other words, the 95% confidence interval for a one-day count where 1,000 pedestrians were counted would be 138 to 1,856 pedestrians. However, the relative standard deviation drops rapidly such that for many sites after 5 – 10 days of sequential counting the relative standard deviation drops to below 10%. Beyond this period the improvement in accuracy is marginal until perfect accuracy is obtained at 194 days (i.e. the total number of non-holiday weekdays in the year).

If anything this analysis likely understates the level of variation in walking demand because (a) the sites are generally very busy (median AADT of 10,000), and (b) the sites are dominated by transport walking activity, which would be expected to have less interday variation than recreational walking. In other words, it is concluded that:

- at busy transport-dominated sites at least five sequential weekdays of counts are required to have a robust indicator of *average* weekday demand (ADT), and
- at quiet or recreation-dominated sites much longer periods are likely to be required.

The only practical means by which such long data collection can be undertaken is with automatic counts.

While the observable component of this variation (i.e. that component due to observable events such as weather) may be adjusted for there will always be some unobservable variation (i.e. random) which cannot be corrected. There have been very few attempts to develop corrections using weather data of pedestrian data, but it is hypothesised that such models would in any case have at best very limited transferability given the importance of context (particularly trip purpose) in influencing weather-related impacts on pedestrian demand.



*Margin of error at the 95% confidence level*

- **Figure 3.1: Sampling error by number of sequential count days for City of Melbourne counters (based on 2019 data for non-holiday weekdays across 38 counters)**

Unlike the earlier London guidance (TfL 2007) more recent London guidance does not provide indicative margins of error but instead proposes count periods varying by context as shown in Table 3.1.

- **Table 3.1: Pedestrian count duration by context (TfL 2019)**

| Type | Description | Hours | Duration | Days |
|---|---|---|---|---|
| High Street | Areas dominated by retail and food premises | 7 am – 7 pm | 5 mins every ½ hour on footpaths<br>5 samples every ½ hour on crossings | One mid-week day and Saturday |
| Office and retail | Areas dominated by substantial Govt and/or commercial buildings | 7 am – 7 pm | 10 mins every ½ hour on footpaths<br>10 samples every ½ on crossings | One mid-week day (Tue, Wed or Thu) |
| Residential | Private residences facing directly onto the street | 7 am – 7 pm | 5 mins every ½ hour on footpaths<br>5 samples every ½ hour on crossings | One mid-week day and Saturday |
| Tourist attraction | Areas with high tourist activity | 7 am – 7 pm | 5 mins every ½ hour on footpaths<br>5 samples every ½ hour on crossings | Saturday |
| Transport interchange | Railway stations and busy bus stations | 7 am – 7 pm | 10 mins every ½ hour on footpaths<br>10 mins every ½ hour on crossings | One mid-week day (Tue, Wed or Thu) |

To overcome the short-period variation in pedestrian counts permanent, automatic counters are desirable. There are several automatic counting technologies available that have a proven track record:

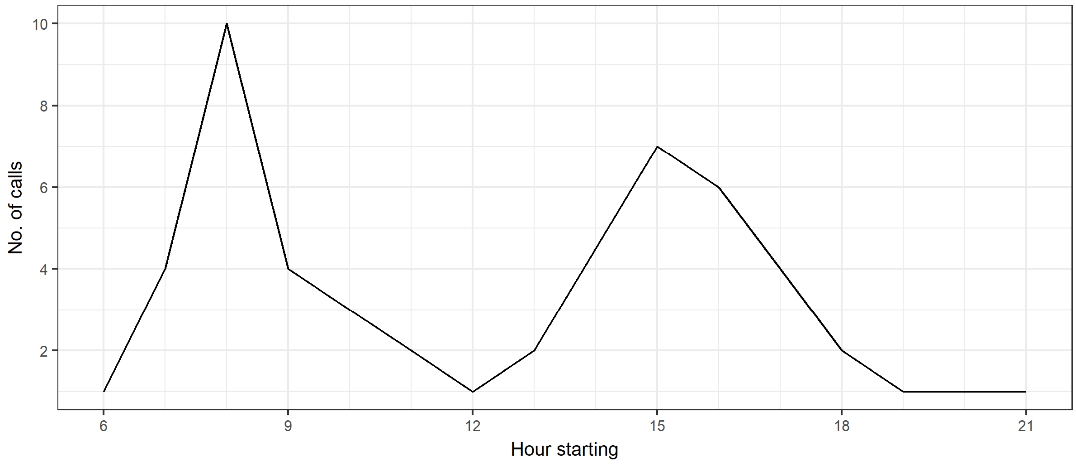
- **Side-facing passive infrared:** used by Brisbane City Council and several regional councils on shared paths and footpaths
- **Overhead passive infrared:** used by the Department of Transport and Main Roads on a number of bikeways in Brisbane, for example the Normanby Bikeway and Goodwill Bridge, and by the City of Melbourne on footpaths.
- **Overhead laser scanner:** used by the City of Melbourne
- **Overhead 3D camera / video analytics:** used by the City of Melbourne.

The largest and most experienced user of automatic pedestrian counters in Australia is the City of Melbourne, which has a network of over 50 counters throughout the inner city. While several technologies of different eras are currently used (overhead passive infrared, laser scanners and 3D cameras) they are progressing towards replacing the infrared and laser scanners with 3D cameras as the latter has proven to be the most accurate and lowest cost solution.

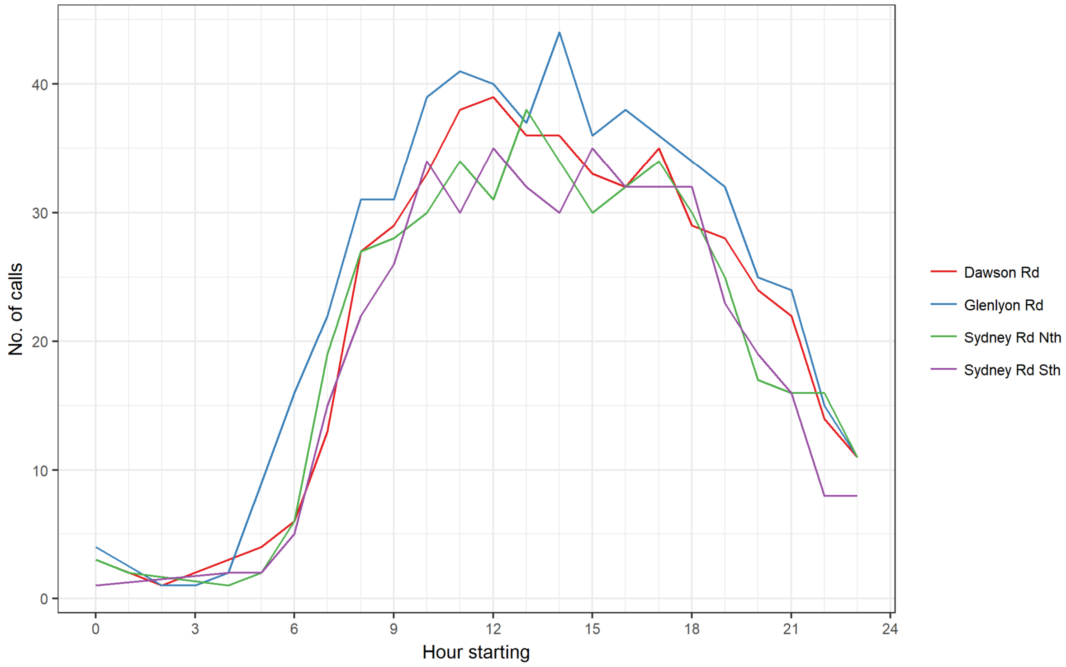
### 3.3.3 Pedestrian operated signals: STREAMS signal logs

There is very little data available on pedestrian demand at pedestrian operated signals, either standalone or as part of signalised intersections. What does exist are generally *ad hoc* counts and there are no before-after counts or intercept surveys understand the change in behaviour that this common form of pedestrian infrastructure creates.

While no counts data is available most traffic signal controllers log the time at which a pedestrian calls the pedestrian phase at signals (that is, when the first pedestrian to arrive presses the button). These logs, self-evidently, do not provide a count of individual pedestrians using the crossing. Nonetheless, as shown in Figure 3.2, the time-of-day distributions of these events appear to be plausible. In Figure 3.2a the pedestrian operated signal demand is dominated by peaks in the hour starting at 8 am and 3 pm, which is consistent with demand dominated by school children. The time-of-day profile in Figure 3.2b is again consistent with an inner suburban shopping precinct where pedestrian demand is greatest during daytime hours. The latter appears to saturate at between 30 and 40 calls per hour, that is a call in every signal cycle. Similarly, Day et al. (2011) analysed a signalised intersection in the USA over an 18 month period and identified plausible variations in pedestrian signal actuations with time of day, day of week, university status (the site being near a university) and weather conditions.



**(a) Pedestrian operated signal across arterial road in residential area and school**



**(b) 4-arm signalised intersection on arterial road in retail precinct**

- **Figure 3.2: Pedestrian signal calls by time-of-day**

Using the signal logs to measure pedestrian demand will severely undercount where there are:

a) more than one pedestrian present, either as part of a group that initially call the pedestrian phase or others that arrive later, and

b) pedestrians who do not press the button and instead cross during a gap in traffic.

A simple, single expansion factor for a site may be inadequate to correct for this undercounting; instead, the expansion will likely vary by time of day and day of week.

Moreover, beyond a level of demand that results in a pedestrian call every cycle it will not be possible to determine an expansion factor – that is, it is highly unlikely the logs would discriminate between a count of 200 or 2,000 pedestrians per hour. However, for crossings with low to moderate demand (and modest peak periods) it may be possible to determine feasible expansion factors.

If it were possible to determine an expansion factor, or factors, to apply to pedestrian operated signals, this would provide a rapid and extremely low cost means of estimating pedestrian demand at the many hundreds of signalised pedestrian crossings in Queensland. This data would be helpful for demand forecasting as it could serve both to:

- act as a demand database of many sites that could be used in a comparison method – i.e. for a prospective site the practitioner could select site(s) that are similar from the database to use for demand forecasting, and
- assist in developing predictive models based on local land uses and the road network.

To assess the feasibility of this approach, cycle analyser data for a pedestrian operated signal in suburban Brisbane[3] was examined across three days. The signal actuations were compared against observed pedestrian counts and a simple linear regression was fit between the hourly count of pedestrian signal actuations and the true pedestrian count. The correlation coefficient of $R^2 = 0.94$ suggests a good fit[4], as does visual inspection via Figure 3.3. The signal actuations consistently undercount pedestrians as expected and do so by an average factor of 2.19. After adjustment the counts align quite closely with the observed counts albeit that some of the peaks and troughs are not captured. Overall, once the expansion factor of 2.19 was applied 35% of the predicted hourly counts fell within 10% of the true values, and 58% fell within 20%. These results are encouraging insofar as they suggest calibration of the pedestrian signal actuations may be practical[5]. However, it is noted that the demand at this site tends to be fairly steady across much of the day and at moderate levels (up to 30 – 40 pedestrians/hour). Sites that experience much larger peaks, such as around school times or commuting times, are likely to exhibit more time-variant undercounting from the pedestrian actuations data. Further work would be required across a range of sites to ascertain whether this process could adequately correct for undercounting, but it is noted that:

- the signal logs exist, and are readily available for analysis at negligible cost, and
- the almost complete absence of any data currently suggests that "something is better than nothing" (assuming that "something" is not misleading).

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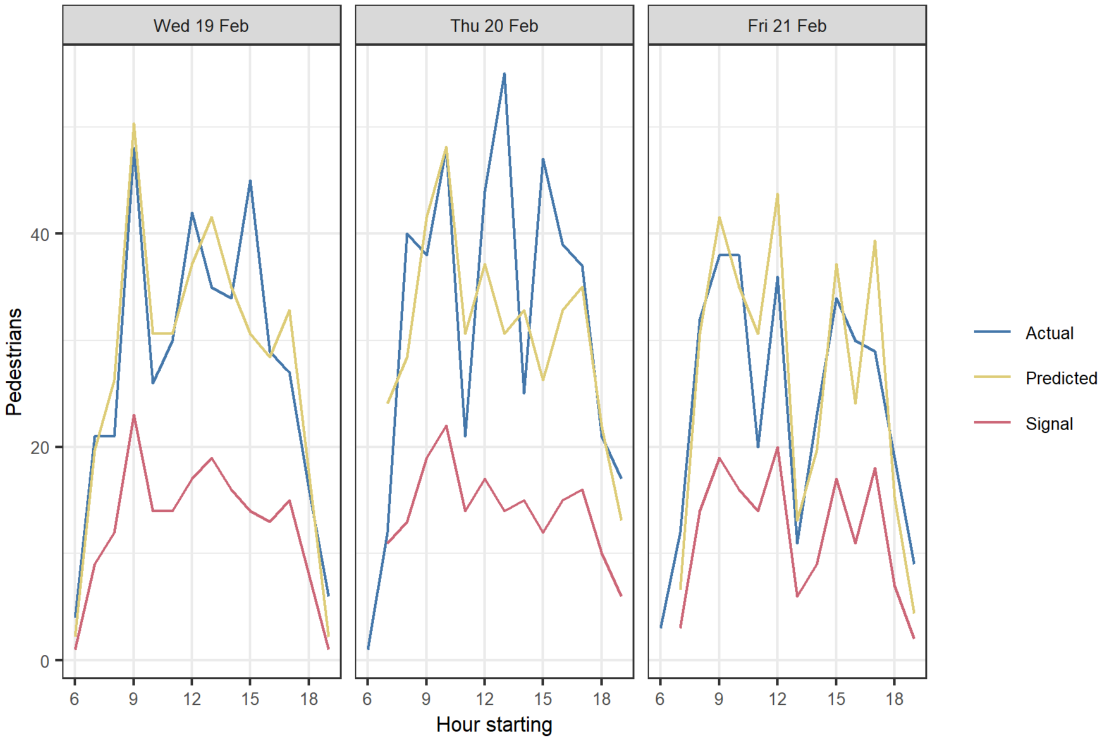
[3] The location is Wembley Road in Logan near the entrance to the Logan Central Shopping Centre: https://goo.gl/maps/CMozrF7zze6bQ6s16.

[4] Caution is required in using $R^2$ as an indicator of model quality in this instance due to the spread in the data

[5] It is noted a naïve linear regression was used which does not account for influential outliers; tests with robust regression methods would be warranted for a real model. Moreover, the model is applied to the estimation dataset. To fully test the predictive accuracy of this approach would require cross-validation, where for example a model is estimated on eight sites and then validated against four sites which were not part of the estimation set.



- **Figure 3.3: Linear regression model fit for a pedestrian operated signal using STREAMS cycle analyser data and observed counts**

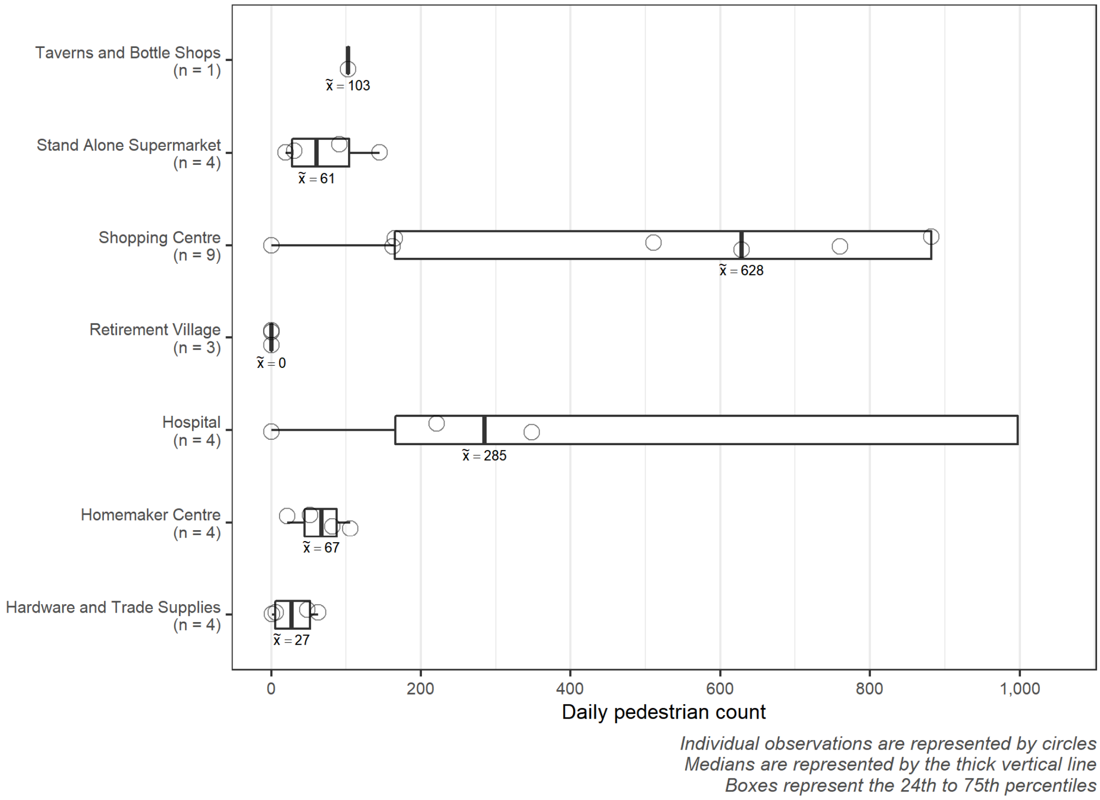
### 3.3.4 Trip generation

It is common for authorities to maintain databases of vehicle, and sometimes person, trip generations from common land uses (e.g. shopping centres, hotels, supermarkets, offices) for the purpose of undertaking traffic impact assessments. These sources include:

- TMR traffic generation data: https://www.data.qld.gov.au/dataset/traffic-generation-data-2006-2018
- NSW Roads and Maritime Services (RMS 2013a)
- TRICS (Trip Rate Information Computer System), a UK-based database of trip generation rates for different land uses (http://www.trics.org/).

TMR has guidance (TMR 2018) for traffic impact assessments that suggest the most preferable source of traffic generation data are surveys of existing developments similar to the proposed development, followed by traffic generation data maintained by TMR (discussed below) and then generation rates provided by NSW (RMS 2013a). The latter include, in some instances, both vehicle trip rates and person trip rates. Most traffic impact assessment guidance focuses on vehicle movements and offers no guidance on mode split and potential pedestrian demand beyond noting that sites with good pedestrian provision and accommodating land uses may have higher pedestrian demand.

The TMR traffic generation dataset consists of 407 sites for which data was collected between 2006 and 2018, of which 29 include pedestrian counts. Of these 29 sites nine are shopping centres with a median daily pedestrian trip generation of 628 trips. The small sample sizes and wide variation between sites make it difficult to generalise this data, in part because the trip generations tend to vary markedly and partly because the site descriptions do not provide information on size to assist in developing trip rates (e.g. trips per 100 m$^2$ GFA).



- **Figure 3.4: Average daily pedestrian traffic at sites listed in TMR traffic generation dataset**

While the sample size of pedestrian trip generations is probably too small to be useful trip generation databases can assist in providing an indication of total traffic generation by a site which can then be split into a walking share. This procedure is often used in the case studies discussed in Section 5.

Overall population walking trip generation rates can be estimated from QTS. A rapid analysis of the 2017 – 19 QTS suggest that males make 0.48 walking trip stages per day and females 0.58 walking trip stages per day[6].

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[6] These estimates are based on unweighted trip stages from the QTS 2017 – 19 for all regions. The walking trip generation rates are highest among teenagers (around one trip stage / person / day) and fairly stable among adults at around 0.5 trip stages / person / day.

## 3.4 Surveys

Two types of surveys are considered here:

- Travel surveys: often called household travel surveys, these are (usually) continuous surveys of a sample of households to obtain detailed travel information over one or more days of all household members
- Intercept surveys: surveys of pedestrians to obtain information such as trip purpose, origin and destination and qualitative opinions of walking in the area.

### 3.4.1 Travel surveys

Travel surveys (or diaries) are the single most important dataset for transport models. They consist of records by all individuals within a household of all trips outside their premises over a period of time – usually one day to one week. The Queensland Household Travel Survey (QTS) is an example of this type of survey. Two relevant issues which arise with regard to the recording of walking trips that are discussed in this section.

#### *3.4.1.1 Route choices and trip distances*

Most travel diaries continue to be largely respondent-recorded exercises that record, for example, a trip from a home address to a workplace, then to a shop, and then home. The *route* by whatever mode is not recorded except for rare surveys where respondents are given GPS devices to precisely record their movements over the survey period. Usually, the time of departure and arrival will be recorded by the respondent – normally they will self-report to a convenient time interval such as the nearest 5 or 10 minutes. The trip distance is then estimated as an assumed speed divided by the travel time. Sometimes it is instead estimated using the crowfly distances between the origin and destination multiplied by a *circuituity* factor in recognition that in any practical network a traveller will have to take an indirect route to their destination. This circuituity factor will be some value above one, usually around 1.3, indicating that the walking distance is 30% longer than the crowfly (shortest) distance. Regardless of the method by which the walking trip distance is calculated there is clearly a degree of uncertainty in the trip distance estimate, and little to no information on the route choice.

#### *3.4.1.2 Trip chaining*

All travel is likely to involve at least some walking. Travel diaries such as the QTS adopt several procedures which affect how walking is recorded:

- *Trips* are defined as one-way travel movements with a single purpose but may involve several modes; *stops* (or *trip stages*) are one-way travel movements for a single purpose and a single mode. A commuting trip to work involving walking to a train station, a single train journey, and then a walk to a workplace would be one trip and three stages (walk-train-walk).
- Trips that start and end at home, for example just going for a walk, are split into an out and return trip of half the total reported duration.

- Walking trips that occur, for example, entirely within the home, or walking from shop to shop within a shopping centre, are excluded.
- Access and egress walking trips to and from public transport are included. However, walking trips to or from cars are included only if explicitly recorded by the respondent – this means that, for example, many walking trips from a residence to a car parked on-street, or from a car park into a shop, are unlikely to be recorded.

The 2017 – 19 QTS dataset suggests that 14.7% of trips involve at least some walking and just over half of these, or 8.8% of all trips, are walking as a sole mode[7]. Of these trips that are walking as a sole mode the most common trip purpose was recreation (37%), followed by education (15%) and shopping (14%). Virtually all QTS trips that involve public transport are multimodal, often with a walk stop at either or both the access and egress end of the trip. However, 59% of car driver trips are recorded as involving only driving, as are 24% of car passenger trips (Figure 3.5). It is possible the proportion of sole mode car driving trips is somewhat overstated because of the absence of these short walks between car parking and a destination. The significance of this underreporting will depend on the purpose to which the data is being used.

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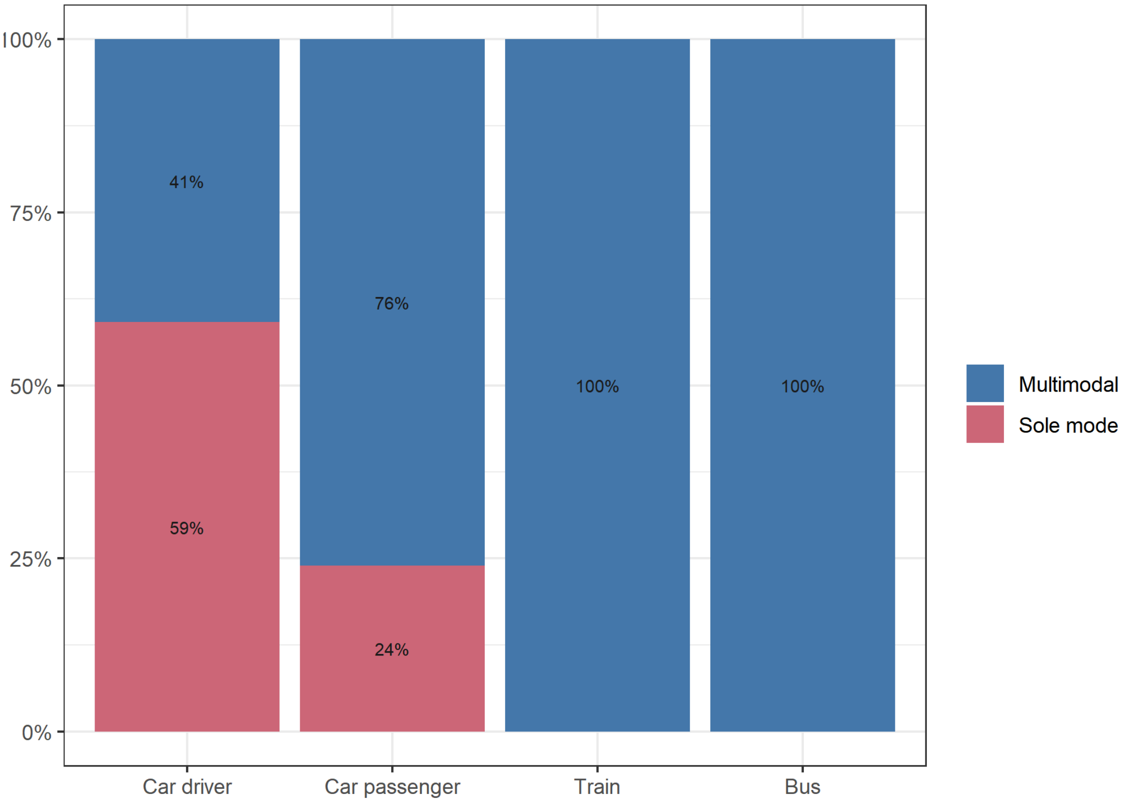
[7] This analysis is based on the fully QTS dataset, for all regions, between 2017 and 2019.



■ **Figure 3.5: QTS trips that are sole mode or multimodal**

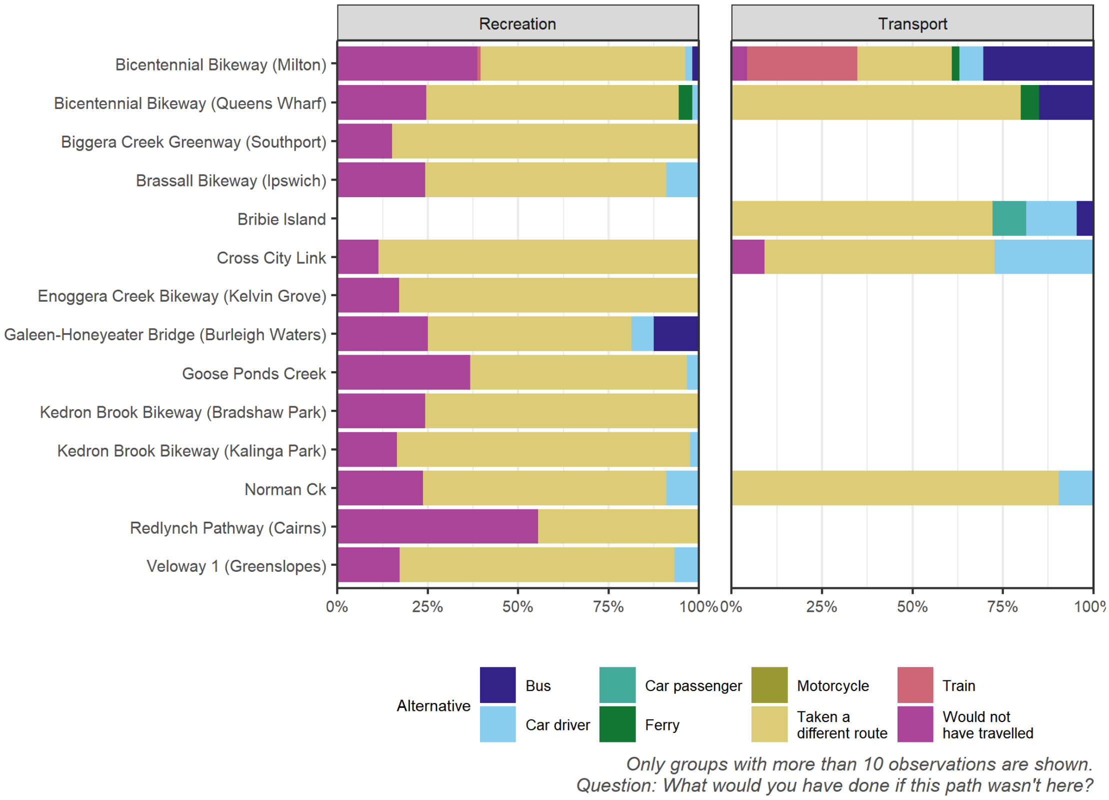
### 3.4.2 Intercept surveys

Intercept surveys provide a relatively low-cost means of *understanding* the motivations and behaviour of those that are walking. The main limitation of this method is that those choosing not to walk at the intercept site will, self-evidently, not be captured. The most useful data that can be obtained from pedestrian intercept surveys are likely to be:

- trip purpose,
- origin and destination,
- basic demographics (gender and age),
- perceptions towards safety and comfort at the location, and
- self-reported changes in behaviour that may have occurred over time, particularly when evaluating new infrastructure.

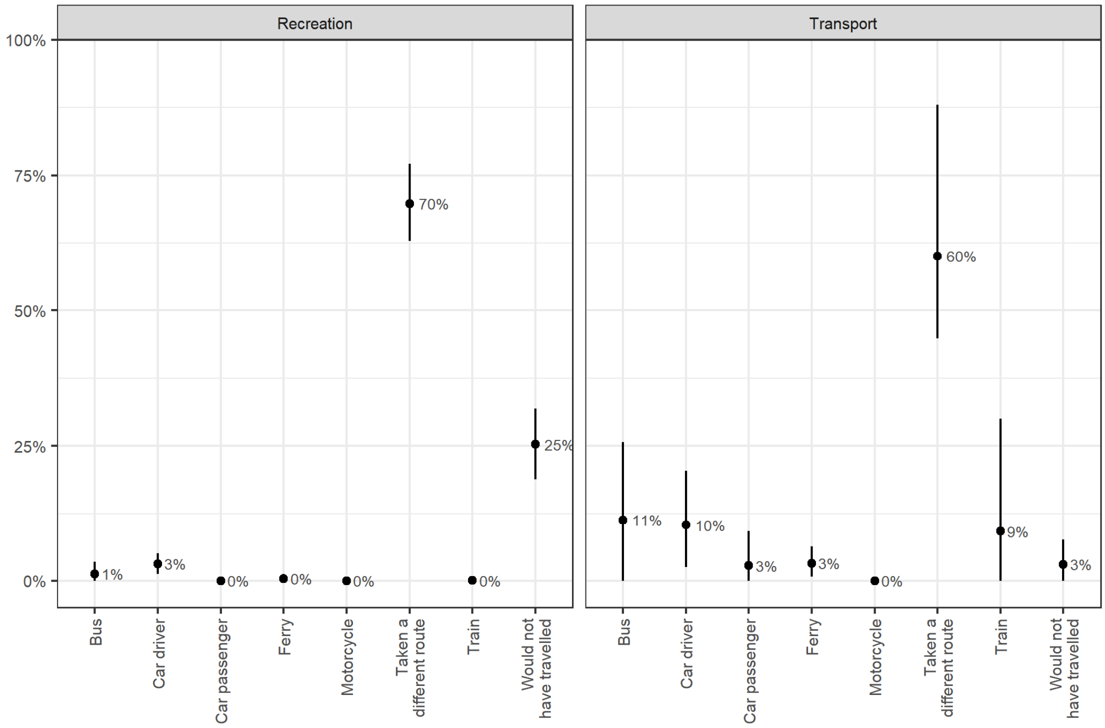
The changes in behaviour are likely to be most insightful in terms of improving understanding of the impact of interventions such as building new pedestrian infrastructure have on encouraging new walking trips – whether they be as a result of mode shifting or all-new walking trips for recreation. It is this latent demand which is least understood, and hence warrants most research attention.

TMR has conducted a large number of intercept surveys post-construction of active transport infrastructure over the past ten years where facility users were asked what they would have done if the facility were not present. Of these surveys, 14 projects had a sufficient sample size of pedestrians to obtain data on diversion. As shown in Figure 3.6, most pedestrians walking either for recreation or transport would otherwise have taken a different route – but still would have walked. An indication for the induced demand is provided by the proportions who indicated they would otherwise have used a car or public transport for their trip. These proportions are generally small for recreation trips, as would be expected, but account for up to around 35% of transport walking trips. There is also a significant proportion of all-new walking travel generated for recreation purposes, accounting for 11 – 55% of recreation walking trips.



- **Figure 3.6: Diversion rates from intercept surveys in Queensland**

The average diversion rates from this data are shown in Figure 3.7. This reinforces the finding that most (70%) recreation walking trips would have occurred irrespective of the project, as would 60% of transport walking trips. However, on average 25% of recreation trips are all-new trips and in the order of 36% of transport trips would otherwise have been made by another mode. These proportions provide insight into possible uplift factors that could be applied to estimate latent demand for walking projects.



*Circles are average values and lines are 95% confidence intervals*

- **Figure 3.7: Average diversion rates by walking trip purpose**

## 3.5 Innovative methods

This broad group include methods such as:

- GPS tracking / logging
- MAC address scanners, and
- Google Streetview.

The first of these involves either a dedicated GPS device or data collected by one of the major smartphone manufacturers (i.e. Apple or Google) using smartphone GPS data. Most smartphone users accept the default privacy settings which allow Apple and Google to record the phone position using GPS – this feature is known as location tracking. This provides a rich dataset on individual travel over a long period of time that has been used for urban planning and mobility research (Bassolas et al. 2019; Ruktanonchai et al. 2018) and to study walking behaviours of specific population cohorts (Khanal, Edwards, and Corcoran 2019). However, the mode of transport has to be inferred from this data. This is usually done using a combination of location and speed; for example, a trip on a highway or railway line is highly likely to be by motor vehicle and train, respectively – and a trip made at an average speed of 60 km/h is highly unlikely to be a walking or cycling trip. This data is likely to be most useful for route choice modelling and less useful for estimating walking trip generations as it will tend to underreport trips given that not all of the population have smartphones, not everyone takes their phone on all journeys, and some users disable location tracking.

MAC address scanners are devices which detect the unique Media Access Control (MAC) address broadcast by device with Bluetooth or Wi-Fi communications. The device does not need to be in discoverable mode for this MAC to be broadcast (although the Bluetooth or Wi-Fi radios need to be switched on at the device), and devices can be detected at ranges in the order of 50 m depending on antenna gain and interference. The MAC address contains no personally identifiable information. Abedi et al. (2013) conducted experiments with these scanners in Brisbane, including at the Goodwill Bridge, to attempt to detect and classify pedestrians, runners and bicycle riders using the bridge. Because these devices rely upon users having a device they are not appropriate for counting – instead they could be used as part of a cordon to provide data on travel times and route choices. In central city areas, or areas with dense footpath network, it can be difficult to tune the scanner to ensure detection only of devices on the footpath of interest – and to exclude devices in motor vehicles if adjacent to a roadway. Trials conducted to understand pedestrian movements into and out of an inner city park in Melbourne (CDM Research, unpublished) found it was difficult to adjust the detectors to avoid triggering from devices in vehicles, and that in relatively confined areas (300 – 500 m across the longest dimension) it was difficult to reliably ascertain that a pedestrian had entered or exited at a particular footpath through the park. However, for larger spatial scales – perhaps suburbs or larger, it may be feasible to use this approach to understand origin-destination movement patterns and walking travel times.

One approach that has been explored to estimate areas of high pedestrian demand on existing footpaths are automated analyses of Google Streetview images (Chen et al. 2020; Yin et al. 2015). These methods show reasonable count accuracy from the images but of course are severely limited insofar as these counts are not directly transferable to pedestrian demand. They are unlikely to be helpful for pedestrian demand forecasting purposes.

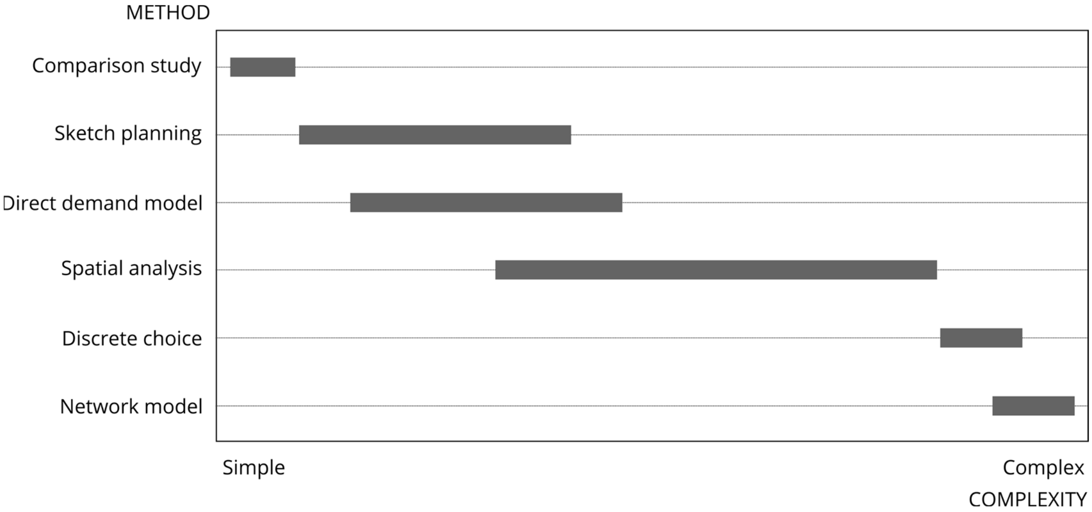
# 4 Forecasting methods

## 4.1 Introduction

The purpose of this section is to review typical approaches to forecasting pedestrian demand. While the methods do not always fit neatly into groups they are divided here for convenience into five groups in ascending order of complexity:

1. Comparison studies (or similar conditions studies)
2. Sketch planning
3. Direct demand methods (or aggregate behaviour models)
4. Spatial analysis, and
5. Transport modelling (including discrete choice modelling).

While comparison studies are almost always simple to use (assuming data is available), discrete choice and network models are invariably complex and require specialist expertise (Figure 4.1). The complexity of sketch planning methods, direct demand models and spatial analysis can vary widely from relatively modest complexity to become quite sophisticated.



■ **Figure 4.1: Complexity of forecasting methods**

## 4.2 Comparison studies

Comparison studies are the simplest and most intuitive approach to demand forecasting. This method involves simply identifying another existing project that is similar in scope and context to the proposed project and using the observed demand from that existing project as a forecast for the proposed project. Where data from several similar projects are available an average could be used, or professional judgement applied to interpolate or extrapolate from the comparison projects.

While TMR and councils have a fairly extensive collection of *ad hoc* pedestrian counts obtained over the years they are not available in a consistent data format that could be readily used by a practitioner. Ultimately it would be beneficial for TMR to maintain a data repository on pedestrian counts, along with site descriptions, such that practitioners can rapidly perform these types of analyses. Moreover, this repository would be very useful to assist in calibrating and sense-checking any of the more sophisticated methods discussed below.

This method can become more sophisticated once demand from multiple existing projects are available; in these situations it may become feasible to develop multivariate regression models that relate observed demand to descriptive variables involving land use (e.g. population, employment) and infrastructure (e.g. presence of footpaths, road traffic volumes). In the existing guidance this method is sometimes referred to as an aggregate model[8] or direct demand model[9] and are discussed further in Section 4.4.

## 4.3 Sketch planning

Sketch planning methods are rules-of-thumb approaches to estimating walking demand. These methods often make assumptions about the total trip generation and then apply mode split assumptions to estimate walking demand, or instead rely upon assumptions of walking trip generation directly. The trip generation is determined by examining nearby land uses – for example, residential areas and major trip attractors such as retail and entertainment precincts. The distribution and route choice steps will vary but are often based on arbitrary assumptions based on the adjacent land uses and walking network.

A trip generation approach is widely used in development applications for estimating motor vehicle demand but there is very limited data on pedestrian trip generation (Section 3.3.4). An example of using trip generations to estimate the walking demand for an inner city office development is in AECOM (2018) and described in Section 5.2.1. However, even if the trip generations can reasonably be estimated they must still be linked to destinations and allocated (assigned) to particular routes; it would be unusual for a trip generator to have only one walking route to and from the location. As demonstrated by the AECOM example this distribution process is often arbitrary – they assumed pedestrian demand from the new uses at the development would split equally in left and right directions onto the footpath immediately in front of the building while existing uses would split proportionally in accordance with the existing counts.

Where there are multiple destinations available either a gravity model or simple discrete choice model can be applied. To illustrate an example of the latter consider a trip generator and three destinations shown in Figure 4.2; the three destinations A, B and C may be thought of as residential areas with a population of 450, 700 and 500 respectively. Residential area A is 0.2 km from the trip generator, while both B and C are 0.5 km away.

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[8] For example, NZTA (2009) refer to these as “aggregate behaviour” models.

[9] For example, Kuzmyak et al. (2014).

The likelihood of choosing a particular route is, intuitively, going to be a function of both the population and distance from the generator. Mathematically this can be expressed as:

$$\Pr(D_i) = \frac{p_i \cdot e^{\beta d_i}}{\sum p_i \cdot e^{\beta d_i}}$$

where *Pr(D<sub>i</sub>)* is the probability of choosing destination *i*, $p_i$ is the population of destination *i*, $d_i$ is the distance to *i* and $\beta$ is a scaling factor. The scaling factor is an indicator of the model sensitivity – the value is negative to indicate a disutility associated with longer distances, larger negative values indicate the model is more sensitive to differences in trip distance. In the absence of local data values from strategic transport models may be suitable[10]; the factor is -1.1594 for white collar commuting trips in BSTM and ranges from -0.5842 (home based tertiary education travel) to -1.125 for commuting trips in the Sydney STM (all values are per km). As a rough guide it may be reasonable to assume a value of -0.8 for education dominated trips and -1.1 for commuting and shopping trips. If it were estimated that the trip generator creates 1,000 commuter walking trips per day the number of walking trips from the generator to A would be:

$$\Pr(A) = \frac{450 \cdot e^{-1.1 \cdot 0.2}}{450 \cdot e^{-1.1 \cdot 0.2} + 700 \cdot e^{-1.1 \cdot 0.5} + 500 \cdot e^{-1.1 \cdot 0.5}} = 33.6\% \times 1{,}000 = 336\ trips$$

The number of trips to B and C would be 387 and 277, respectively; the differences in the demand between these two equidistant destinations is equal to the differences in their respective populations.

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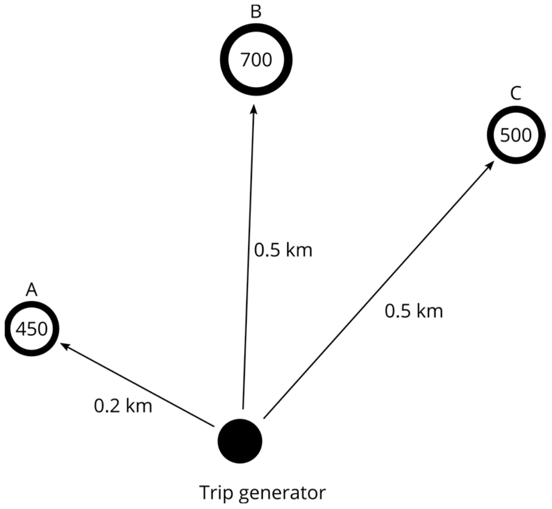
[10] Strictly, these scaling factors are derived from mode-destination choice models but this simplified example ignores the mode choice step.



- **Figure 4.2: Simple network with one trip generator and three destinations**

## 4.4 Direct demand models

Direct demand models attempt to find a statistical relationship between land use and transport variables and observed demand, and then to apply these models to other locations or scenarios for the purpose of demand forecasting.

Two examples of these types of model, both from the USA, are the Seamless Travel Model developed from data in San Diego (Jones et al. 2010) and a similar model developed in Santa Monica (Haynes and Andrzejewski 2010). Both models relate peak hour pedestrian demand at intersections to land uses (population density, employment density and retail functions for the Seamless Travel Model) and, in the case of the Santa Monica model, the transport network (bus service frequency and motor traffic speed limits). The Seamless Travel Model predicts 7 – 9 AM pedestrian demand as follows:

$$P_{AM} = 1.555 + 0.723ED + 0.526PD - 1.090R$$

where $P_{AM}$ is the 7 – 9 AM pedestrian count, *ED* is the employment density within 0.5 mi, *PD* is the population density within 0.25 mi and *R* is the presence of retail destinations within 0.5 mi. Expansion factors were then applied to this result for each of the following conditions:

- More than 100 households without vehicles within 0.5 mi = 0.67
- Greater than 6,000 public transport trips within 0.25 mi = 2.14
- Four or more shared use paths within 0.25 mi = 1.5

The latter two of these expansion factors seems to be plausible; that is, locations with more public transport usage or more shared use paths would be expected to increase walking demand. However, the finding that higher levels of non-car ownership would *decrease* walking seems counterintuitive. Moreover, while increasing population and employment density are predicted to increase pedestrian demand it is not clear why the presence of retail would *decrease* pedestrian demand[11].

The Santa Monica model has the following form:

$$P_{PM} = 222.18 + 0.00321ED + 3.675BF_{PM} + 82.695SDP - 0.00685DO - 5.999SL$$

where $P_{PM}$ is the 5-6 PM pedestrian count, *ED* is the employment density within 0.33 mi, $BF_{PM}$ is the PM bus frequency, *SDP* is 1 if the intersection is within a shopping district, *DO* is the distance (mi) from the ocean and *SL* is the average speed limit. The signs and magnitudes of the coefficients int his model appear to be plausible.

The guidance commissioned by NCHRP (Kuzmyak et al. 2014) provide an insightful critique of these methods, in particular the absence of a causal relationship between the predictor variables and demand:

> *Multiple regression is used to quantify the association, and both respectable $R^2$ values and good parameter statistics suggest that these models are effective in explaining levels of activity. However, because the models are created with highly aggregated data to represent both the dependent (counts) and independent (explanatory) variables, and the explanatory variables often have little direct "causal" relationship with the activity level, their reliability for forecasting often carries some doubt. Hence, their applicability is limited to the specific area for which they were developed and to the variables included in their structure.*
>
> *(*(Kuzmyak et al. 2014) *p. 8)*

In other words, correlation isn't necessary causation. However, despite the lack of behavioural structure to these models they do offer the advantage of simplicity despite the risks associated with their use as forecasting tools.

## 4.5 Spatial Analysis

This category of models use spatial analysis to forecast pedestrian demand, usually indirectly via accessibility, walkability or propensity measures. That is, rather than explicitly predict the demand they instead estimate the attractiveness and hence propensity that travellers in an area may walk. While all transport models are inherently spatial the models considered here differ insofar as they do not seek to directly forecast demand by attempting to link trip generations and destinations, and then assigning these origin-destination movements to a network in the way a conventional transport model would work.

### 4.5.1 Space Syntax

Space syntax is a spatial approach to pedestrian analysis that consists of three factors:

1. spatial layout attraction: geometry of the street, including connectivity
2. land use attraction: location, size and type of land uses, and

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[11] However, the effect of retail is minor

3. transport attraction: public transport nodes.

The method was first developed by University College London, and has been commercialised by Space Syntax, a UK urban planning consultancy. The approach is based on network topology including connectivity; this characteristic is measured as "angular movement" whereby a circuitous route that requires, for example, walking around a major building or natural feature, will be penalised more highly than a route that is more direct. The generalised cost between two links is measured using the distance, topological (fewest turns) and geometrical (least angle change) constraints. The method has a distinct advantage over transport modelling insofar as it does not require data on pedestrian movement. However, the approach differs from transport models in that it doesn't provide a quantitative estimate of demand but instead provides a *spatial accessibility value* to each link that is an indication on the attractiveness of that link. This index cannot be directly correlated to demand and hence it cannot be used in cost-benefit analysis or for level of service estimation. However, as noted below there have been studies linking the accessibility value obtained from the topological analysis to observed pedestrian counts in order to map the accessibility onto demand.

Proponents of the space syntax approach argue around 60% of pedestrian movement can be explained purely from the topological characteristics of the network (Jiang 2009). Much of the remainder are argued to be attributable to the functional attributes such as land use type and density and public transport nodes. While this method cannot directly estimate pedestrian demand there have been case studies where the spatial accessibility index is correlated to demand using land use attributes (Lerman, Rofè, and Omer 2014). In this example from Israel a correlation coefficient ($R^2$) of 0.62 was obtained from 69 manual counts across a network of 1,434 links. Dependent variables were the space syntax topology variables and functional variables of residential density, presence of commercial shopfronts and proximity to public transport. Other implementations, for example in Boston (USA) reported a correlation coefficient of 0.81 using distance to public transport and major tourism attractions as dependent variables (Raford and Ragland 2006).

While this method may be useful to identify walking potential, and demonstrate the importance of network connectivity in encouraging walking, it is unlikely to be beneficial to practitioners interested in forecasting demand explicitly, especially for modest projects such as pedestrian crossings or pedestrian demand around new developments. Moreover, as noted by Kuzmyak et al. (2014) much of the space syntax method is proprietary and so it is difficult to understand the detail within the method.

### 4.5.2 LUPTAI

The Land Use and Public Transport Accessibility Index (LUPTAI) is used by the Department of Transport and Main Roads as an indicator of walking accessibility to public transport. The tool has been used to assess the accessibility improvements, for example, that would accrue from walking and cycling bridges across the Brisbane River (Bertolaccini et al. 2017). The LUPTAI model shares the limitation in common with other forms of accessibility modelling that it provides an *index* and not a quantitative estimate of pedestrian demand.

As such, this method is not directly suitable for pedestrian demand forecasting other than as a *relative* measure of walking demand – i.e. it could be used to say that walking potential is higher in location A than B, or that walking demand will likely increase/decrease as a result of a change in the transport network or land uses.

### 4.5.3 City of Melbourne

The City of Melbourne commissioned the development of a pedestrian model of the inner city area to assess the economic benefits of improving pedestrian permeability (SGS Economics & Planning 2014). They used a very fine-grained walking network and small travel zones (1,805) of which two thirds were the size of individual properties. This level of disaggregation was only feasible because of the availability of very fine-grained land use and walking network data that had previously been developed by the City of Melbourne. Links in the walking network were assigned speeds arbitrarily from 1 km/h to 4 km/h, with most links having speeds between 3 and 4 km/h. These speeds are somewhat lower than would be typically assumed for an able-bodied pedestrian but are closer to effective walking speeds in the inner city given intersection delays and footpath congestion. Effective job density (EJD; total employment within a 30-minute walking catchment) was used as an indicator of pedestrian network performance. The impact on EJD of improving pedestrian connectivity through additional road crossings and reduced delays were assessed and monetised by making assumptions around labour productivity improvements that may accrue from higher EJD. The shortest time was used for the routing algorithm but the way in which trips were distributed is unclear.

## 4.6 Network modelling

This class of forecasting consists of transport models that are broadly consistent with the well-established practices used for forecasting motorised travel. The vast majority of these models adhere to a four-stage framework (Ortuzar and Willumsen 2001):

1. **Trip generation:** total trips, tours or activities are estimated based on land use and demographic attributes. These trips will usually be split into purposes (commuting, education, shopping, business-related and other as a minimum).
2. **Trip distribution:** trip origins and destinations are linked; for example, trips produced by a predominantly residential zone will be distributed across a number of attractor zones containing employment (for the commuting trip purpose).
3. **Mode choice:** the proportion of trips between each origin-destination pair made by each mode.
4. **Assignment:** trips by mode are allocated (“assigned”) a route across the network.

Models are *estimated* using observed data on travel behaviour, usually using travel diaries such as QTS, and a simplified transport network to estimate the *cost* between each origin and destination. Estimation is the process of fitting a mathematical model to observed behaviour, in much the same way as a simple linear regression model $y = mx + c$ estimates the gradient $m$ and constant $c$ given a set of observed values $x$ and $y$. As part of this estimation the *cost* is some combination of the travel time and cost (e.g. car fuel or other operating costs, tolls and public transport fares). This estimation process will often use discrete choice models, which is a probabilistic framework of assessing the *likelihood* a traveller will choose a destination and mode for their trip.

A review of pedestrian and bicycle models within the transport modelling paradigm found that while most were capable of estimating total pedestrian generation very few carried pedestrians through all modelling stages to assignment (Kuzmyak et al. 2014). Indeed, of the eight approaches reviewed only three explicitly forecast link volumes and two had the potential to do so if complemented by a complementary assignment procedure. Similarly in Australia, the BSTM takes walking through trip generation, distribution and mode choice but does not assign to a network[12]. Most other models, such as the Sydney STM and Victorian Integrated Transport Model (VITM) drop walking trips after the trip generation step[13].

### 4.6.1 Is network modelling required?

Network modelling is a complex, data- and time-intensive task. For many pedestrian projects, and particularly those of relatively low cost, the effort expended is unlikely to be justified. Moreover, models – like all simplifications of reality – will almost always be wrong insofar as the forecasts they provide do not accord with reality. Transport modelling has a patchy history of forecasting accuracy, even for extremely large and complex road and public transport projects where sophisticated transport models have been developed based on extensive data collection (Flyvbjerg, Bruzelius, and Rothengatter 2003; BITRE 2018; Parthasarathi and Levinson 2010). Not only are models often wrong, as argued by Flyvbjerg et al. (2003) they are often biased towards being overly optimistic.

The explanation for these forecasting errors vary and differ across projects. However, it is suggested that the purpose of modelling is not to be accurate *per se* but rather to assist decision makers in assessing various options – the model needs to be fit for purpose and nothing more. What is relevant then is that the model should point the decision maker in the “correct” direction. Given the vast experience and effort expended modelling motorised travel, and the comparatively miniscule effort expended on pedestrian demand forecasting and data collection, it is unrealistic to expect high accuracy from pedestrian demand models. Instead, the issue is whether models can provide forecasts that are sufficiently fit for purpose.

Implicitly acknowledging the practical limitations of modelling pedestrian demand, TIC (2016) suggest an initial preliminary analysis using either sketch planning or qualitative comparison of alternatives. According to this guidance modelling is only justified if one or more of the following conditions are met (TIC 2016) p14:

- The preliminary analysis fails to identify the best course of action
- The project requires a rigorous analysis for approval from decision-makers

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[12] While walking trips are retained in the distribution and mode split stages the simplified network coding will limit the accuracy and validity of the model sensitivity to interventions.

[13] Note however that multimodal trips involving walking, such as walk-train-walk are carried through in these models.

- There are significant risks involved if the recommendations provided are wrong.

These conditions are all subjective but provide practical guidance as to whether modelling is in fact required.

### 4.6.2 Model scales

The geographic coverage of a pedestrian demand forecast will be governed by the type(s) of investment being considered. TIC (2016) differentiate between four scales of models:

1. **Strategic models:** examines the impacts of large-scale transport policy and land use changes at the metropolitan scale
2. **Project models:** assess individual projects, land use strategies and transport corridor issues
3. **Operational design:** assess the detailed operational performance of specific transport infrastructure projects, land use developments and local area traffic management.

Operational design usually involves microsimulation modelling to understand crowd dynamics, which is not in scope for the present study. Project models are likely to be most applicable to walking, as the intent will be to forecast demand for discrete walking projects.

### 4.6.3 Strategic models

Most efforts to develop pedestrian demand models have focussed on strategic models – that is, models that tend to cover large conurbations. These models are almost always multi-modal and sometimes incorporate walking bundled together with cycling as “non-motorised” or “active” modes. An example is the Brisbane Strategic Transport Model (BSTM).

In considering the application of modelling to forecasting pedestrian demand several technical aspects are usually considered:

- **Mode choice hierarchy:** whether walking should be combined with bicycle riding to have one non-motorised mode[14]
- **Travel zones:** the number and size of travel zones, and how short walking trips entirely within these zones (“intrazonals”) should be handled
- **Network coding:** the way in which links on the network are weighted to account for varying walkability
- **Purpose:** how to handle discretionary, non-transport walking activity for recreation – and especially those walking trips for which the activity itself is the purpose (that is, “going for a walk” where notions of providing a shorter route are meaningless or counterproductive[15]). The balance between trip distance (or time) and

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[14] Given the very different speeds and network requirements of these two modes combining them is very unlikely to make sense.

[15] However, investments that provide an improved walking environment *quality* are likely to be valued in these situations.

attractiveness will also differ markedly between purposes – we would expect someone walking for transport to assign a higher weight to the trip distance than someone walking for recreation, for whom the attractiveness of the route would be relatively more important.

- **Person characteristics:** those with mobility impairments will have very different expectations and limitations with regard to their walking activity and preferences.

Xu and Casello (2019) identified five obstacles to improving pedestrian models:

1. A lack of empirical data
2. Inappropriate travel survey design/methods
3. Inappropriate zonal structure
4. Failure to consider pedestrian tours in satisfying activities
5. Failure to develop appropriate cost representations for pedestrians

The Xu and Casello review focussed on activity-based strategic travel models as are widely used in the USA. Most strategic models in Australia, including the BSTM, are trip or tour-based models for which some of these obstacles are somewhat different. Nonetheless, the references to an absence of empirical data upon which to estimate and calibrate models is pertinent, as are limitations around zone structures and inappropriate cost representations (this referring to an absence of accounting for route *quality* in addition to time/distance).

#### *4.6.3.1 Travel zones*

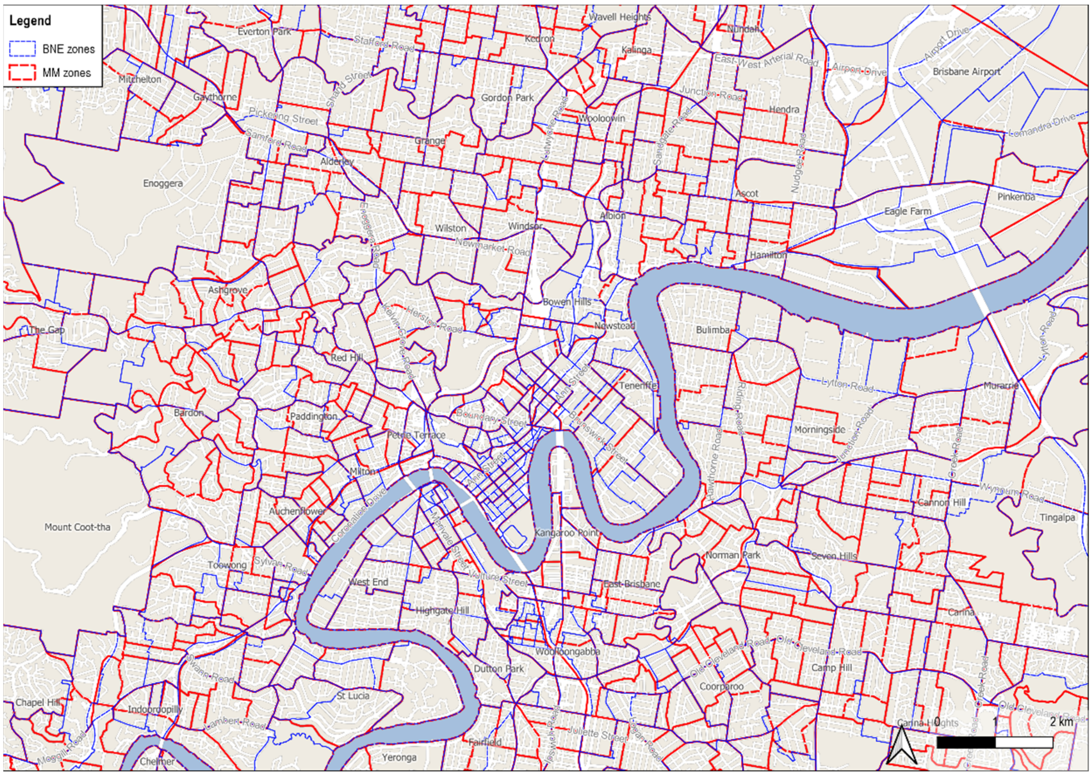
Strategic transport models almost always divide an area into travel zones. The centroid of each of these travel zones is connected to adjacent zones by a link which has attributes affixed which vary by mode. These links are simplified representations of the transport network between these zones. For example, for public transport there will be a time and fare attribute. For pedestrian travel the road network distance between the centroids is used along with an assumed walking speed to provide a time "cost". This time cost almost never includes aspects such as the quality of the walking environment (which, at least for recreational trips would be expected to affect the attractiveness of the link) or delays at signals and is unlikely to accurately represent the distance travelled if (a) there are significant impediments to walking movement across features such as major roads, and (b) if instead there are pedestrian accesses that provide a more direct route than following the road network.

Travel in each travel zone is "loaded" onto the network by centroid connectors, which are imaginary links that account for local travel within the zone to the centroid and thence onto the network. These connectors usually load onto the network at intersections. The pedestrian cost of using these connectors is usually the connector length at a constant speed; RMS for example use 5 km/h speeds for pedestrian intrazonals (RMS 2013b). One potential avenue by which strategic models could marginally improve the way in which they handle pedestrians may be to refine the coding of these intrazonals to better reflect true walking distances within each zone. This would require manual assessment of the local walking network, taking into account the path connectivity.

The BSTM uses two zoning systems:

1. BNE: 1,597 zones down to the block level in the Brisbane CBD (dimensions of around 250 m) and more uniform across the wider model area – this is the standard zone system
2. BSTM_MM: 1,544 zones - larger zones in the Brisbane CBD (around 2-4 blocks per zone, typical dimensions of around 500 m), some more disaggregated zones within the Brisbane City Council area.

An indication of the scale of the zones is illustrated in Figure 4.3 for the inner Brisbane region. Outside the Brisbane CBD the zones vary in size but are generally 500 – 1,000 m across. For major projects across zones, particularly where the zone boundaries are fixed by a major physical barrier such as the river, it would be feasible to use trip generations as part of a project model to forecast demand. However, for many pedestrian projects of a more modest scale the zones are too large to be useful[16].



■ **Figure 4.3: BSTM travel zones (inner Brisbane)**

### 4.6.3.2 Disaggregate models

One potential solution to the challenge of travel zones is to use disaggregate models. These are often used in tour- and activity-based models and rely upon a synthetic

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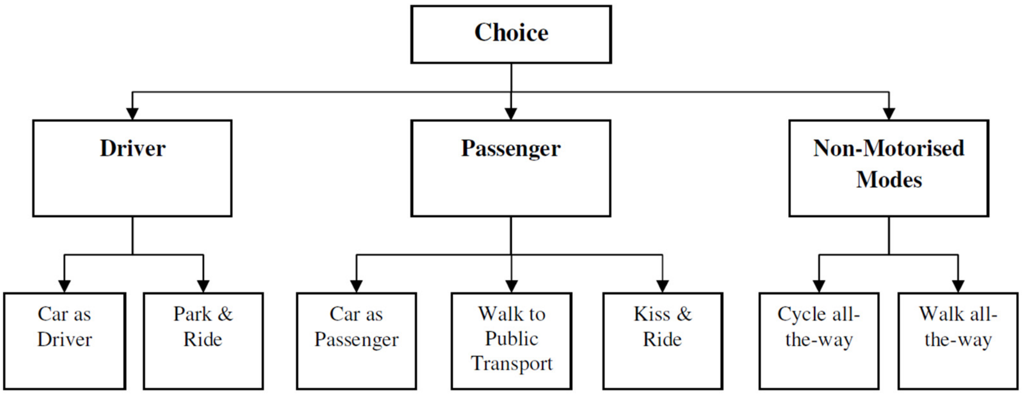
[16] This is not an argument in support of using a finer zone system, as doing so would have major repercussions on runtime and require extensive model re-validation. Most strategic models internationally have in the order of 2,000 zones or less, and very rarely more than 3,000 zones, in order to maintain a practical runtime. However, there may be a case for splitting zones in specific areas where required – but this is likely best done in a project model.

population – usually derived from a travel survey. This approach circumvents the need for travel zones but does not preclude the need for very detailed network coding if assignment of short walking trips is required. An advantage of these models includes the absence of travel zones and hence finer spatial disaggregation –individuals are assigned to a discrete location in space. In turn this means there are no intrazonal movements; all trips are assigned to a network, which will be inherently superior to model relatively short trips such as those made by walking.

#### 4.6.3.3 *Mode choice*

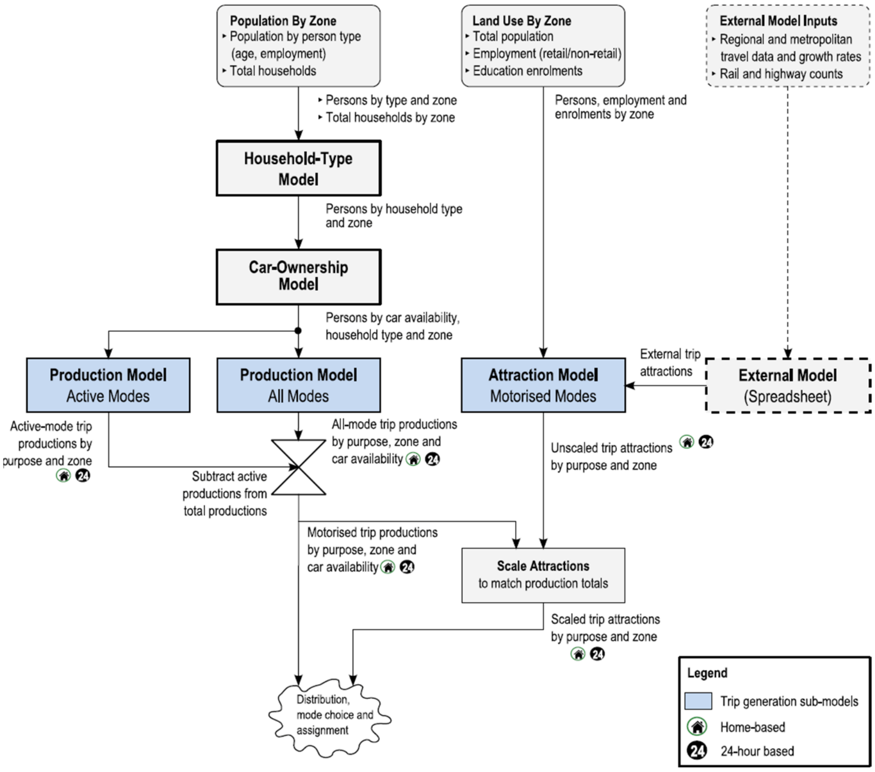
Most strategic transport models, including BSTM, use a multinomial logit mode choice formulation of a structure similar to that shown in Figure 4.4. In this hierarchy walking and cycling are considered as one mode. Clearly, the distance travelled, and speeds achieved by these two modes vary markedly, even if the available networks do not (noting that bicycle riders may legally ride on footpaths, so the walking and riding networks tend to largely overlap). Where a modal split is required between walking and cycling this will often be done as a sub-modal split within an active transport nest as shown in Figure 4.4. Ideally the appropriate model structure would come from the model estimation; however, in practice there are likely to be very few cycling trips and, in any case, inadequate network coding to provide realistic estimates of the cycling and walking costs.



- **Figure 4.4: Commuting (white collar) mode choice hierarchy in BSTM (TMR 2008)**

While the mode choice hierarchy is technically complex to determine a key consideration is the effect it will have on elasticities. That is, the propensity to shift modes will depend on the nesting structure. Modes within a nest (e.g. walking and cycling within an “active transport” nest) will tend to more readily shift between one another than to modes outside the nest. In practical terms this means, for example, that an improvement in walking conditions will tend to attract proportionally more bicycle riders than motorists if active transport are within the same nest. This may, or may not, be behaviourally realistic – the structure should be determined by the best model fit to the data.

The Melbourne Integrated Travel Model (MITM) incorporates walking and cycling pooled together as non-motorised modes (Figure 4.5). A trip production model generates total walking and cycling trips for each travel zone (noting that the modes are *combined*). The trip attractions model consists only of motorised modes; the active modes are not carried forward into the mode choice, distribution or assignment steps.



■ **Figure 4.5: MITM home-based trip generation model structure (SKM and AECOM 2011)**

### 4.6.3.4 *Route choice / network coding*

Network coding in strategic transport models is generally as follows:

- Road links have a free flow speed and speed-flow curve which reduces the speed (and hence increases the travel time) along links according to demand; an iterative approach is used to assign traffic such that once one route approaches capacity (and hence speeds drop) trips are "spread" among other routes. Intersections are not explicitly included, instead travel time surveys are used to "tune" the free-flow speeds to best replicate observed travel times across the network.
- Public transport trips are assigned according to the fastest route, including factors to account for interchange and waiting.
- Walking and cycling, if they are assigned to the network at all, are usually assigned on the assumption of a fixed speed with no capacity constraint.

The main insight is to recognise that trips for roads and public transport are assigned based on the shortest (or quickest) route[17]. While for walking trips for transport travel time is clearly a consideration, there will also be some preference towards routes with a better

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[17] In reality costs will also form part of the model – whether it be tolls and car operating costs, or public transport fares. These are combined with travel time to form a generalised cost (or time) using an assumed value of travel time savings.

quality. There will be any number of factors which play into walking quality – from path gradient, surface quality, trees and shading, proximity to busy roads, personal safety or pleasant views. A review of the literature on correlates of adult walking found that the presence of retail and service destinations, and functional aspects of routes (footpaths and street connectivity) were associated with walking for transport and the presence, proximity and quality of recreational destinations and route aesthetics were important for recreational walking (Sugiyama et al. 2012). There have been several studies using GPS data on walking route choice, including by Broach and Dill (2016), that find pedestrians prefer to avoid turns, busy streets, uphills or arterial or collector road crossings. Many of these attributes are related to interventions which may be desired to encourage walking, and so in principle it would be important to ensure models are sensitive to these attributes. However, developing a realistic representation of a pedestrian walking network would be a very complex undertaking.

#### 4.6.3.5 Destination choice

Destination choice models usually involve an *impedance* and *size*. The impedance is the "cost" associated with the walking trip; that is, usually some function involving distance, delay at intersections and possibly the attractiveness of the walking route. The size is the attractiveness of the destination zone – for commuting trips this may be employment, for education trips it may be the number of school students and for shopping trips some function of the retail activity. Where there is only one trip generator, such as described in the hypothetical example in Section 4.3, a discrete choice model can be used to distribute the trips. However, when there are multiple origins and destinations methods such as gravity models will be required to balance the trip productions and attractions. The development of a destination choice model in Portland (USA) found strong sensitivity to distance for walking trips (Clifton et al. 2016b). For example, one kilometre of additional walking distance reduce home-based commuting walking odds by 57% for car owning households and shopping trips by 75% for households with children.

While transport walking trips have a clearly defined destination such as a supermarket, workplace or public transport node, this is not the case for many recreational walking trips. For example, a walk "around the block" will have home as both the generation and attraction. It is standard practice in travel diaries to code these trips using the farthest point on the trip as the destination and splitting into two trips (i.e. the home to destination outbound leg and the destination to home return leg). How these trips could be incorporated in a destination choice model has not been further investigated.

#### 4.6.3.6 Activity-based models

Activity-based models model individual travel patterns rather than dividing such travel into independent trips or tours. By doing so the travel choices are considered in a more natural way; for example, a parent dropping their child at school before proceeding to work will make their mode choice based on the total activity rather than independently for each leg. While there are distinct advantages of activity-based models insofar as they more realistically account for the linked factors affecting travel choices they do not circumvent the need for travel data upon which to estimate the models nor on highly detailed networks incorporating walking links.

The Melbourne Activity-Based Model (MABM) is one of the few activity-based travel models in Australia. The model covers the Melbourne metropolitan area andis based on the MATsim open source software platform[18] (KPMG and Arup 2017). While walking travel is explicitly modelled within MABM this travel was not subject to validation other than mode shares by region[19]. The model tends to underestimate active modes[20]. While the model is inherently disaggregate in nature and hence allocates all movements to a network the highway network was based on the Victorian Integrated Transport Model (VITM). This network is insufficient both in spatial resolution and link coding to be directly useful for pedestrian modelling. Moreover, there are significant practical limitations of these types of models; the runtimes can be very long; MABM for example can take in the order of five days to run a scenario.

#### *4.6.3.7 MoPeD*

MoPeD (Model of Pedestrian Demand) is a pedestrian model developed by Portland State University (USA) (Clifton 2016; Clifton et al. 2016a; Portland State University et al. 2015) and is entirely based on an open-source GIS platform. The model probably represents the most extensive effort to develop a strategic network model for pedestrians, and so the key features are reviewed here.

The model incorporates trip generation, distribution and route choice but does not include mode choice; that is, it is purely a pedestrian model. The main practical implication of the absence of mode choice is that there will be no in-built sensitivity of the model to induced demand (i.e. all-new walking trips) or demand that may be shifted from other modes as a result of a project. The model uses 80 m x 80 m grids (Clifton et al. 2016a) for the trip generation step but then aggregates these to 400 m x 400 m grids for the destination zones in the destination choice step to reduce computation times. The zones are smaller than are typically used for strategic travel models in order to reduce the proportion of trips that are intrazonal.

The MoPeD model does not explicitly model impedance along simplified links between zones, but rather takes a shortest walking path between a production and attraction zone and applies a weight in the form of the Pedestrian Index of the Environment (PIE) which is a score of the zone's walkability. Detracting from the PIE are barriers such as topography, freeways and industrial employment. In effect, they circumvent the need to code individual links on the network by instead applying a zone-based accessibility index. While this approach avoids the need to explicitly code links between zones, aside from distance, it does make it difficult to test improvements between links such as new or upgraded pathways. Clifton et al. (2016a) recognised the absence of detailed network coding as a limitation of their approach and noted that even if sufficient network data available at a local

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[18] https://www.matsim.org/

[19] See p.15 of KPMG and Arup (2017).

[20] See p. 45 / 46 of KPMG and Arup (2017).

level it would unlikely to be available at a wider metropolitan level. This same shortcoming applies in considering the application of these methods to Queensland.

The model uses a shortest path assignment which means that population heterogeneity is not incorporated; that is, there is no direct accounting for variations among the population in preferences to different quality walking facilities. The most significant shortcoming of the model overall though is likely to be the absence of feedback between the pedestrian network and pedestrian trip generation – that is, the absence of mode shift towards walking that may occur as a result of improved walking infrastructure or indeed the generation of all-new walking trips.

# 5 Case studies

The purpose of this section is to document some practical applications of pedestrian projects where demand modelling was either undertaken or would ideally have been used to support the development of the projects. In each example the context is introduced, followed by a description of the approach taken to demand forecasting (if any) and finally a commentary on the benefits and limitations of demand forecasting in delivering improved outcomes for pedestrians discussed.

## 5.1 Queensland

### 5.1.1 Bundaberg Ring Road

#### *5.1.1.1 Context*

The Bundaberg Ring Road runs from the south of the city across to the northeast and was constructed in around 2009. Immediately to the east of the city Sienna Boulevard runs east from the Ring Road into a housing estate (Figure 5.1). This housing estate has been progressively developed since 2010 and had 547 residents in 2016 (ABS 2017). Around 700 m to the west of the ring road along Kepnock Road is Kepnock State High School, with an enrolment of 1,342 students in 2018 (Department of Education 2019). A school bus runs along Greathead Road to the immediate west of the ring road and informally collects children near Sienna Boulevard. There is also a supermarket located 350 m northwest of the intersection. The posted speed limit is 80 km/h along the ring road and the default urban speed limit of 50 km/h applies along Sienna Boulevard. A speed survey undertaken in conjunction with a road safety audit (TMR 2012b) in 2012 found the 85th percentile speed around the start and end of the school period was 83 km/h. The road safety audit considered this compliance to be satisfactory. There have been no Police-reported crashes involving pedestrians in the immediate vicinity of the intersection over the past ten years.

When the ring road was completed in September 2009 there was no provision for pedestrians to cross the Ring Road near Kepnock Road, the only formal crossing being the signalised intersection of Elliott Heads Road around 1.3 km to the south; there is no footpath on the east side of the Ring Road to provide access to this intersection. The subsequent development of the residential area to the east has created a situation where residents have no safe means of crossing the Ring Road to access the high school, supermarket, or other destinations to the west.

#### 5.1.1.2 Demand forecasts

In response to community concern about the ongoing development in the area and absence of pedestrian crossings, TMR undertook an options analysis in 2012 (TMR 2012a) and noted that:

- Pedestrian crossing demand in the vicinity of the intersection was around 18 pedestrians per day with a peak of 33 on a Saturday. The weekday demand was dominated by school children movements.
- Motor traffic volumes on the Ring Road was around 4,500 vpd in 2011 (more recent counts indicate substantial traffic growth to 5,200 in 2015 and 6,500 in 2018).
- The need for a pedestrian crossing was assessed using TMR's Pedestrian Crossing Prioritisation Workbook. The initial pedestrian demand assumption in the workbook was that observed from the counts – namely six pedestrians (no children) in the AM peak hour and four (two children) in the PM peak hour. Growth of 600% between 2012 and 2032 was assumed based on continuing development of the residential estate, with linear interpolation for intermediate years.
- The analysis from the workbook indicated there was insufficient demand for a facility before 2027, when a median refuge was rated as a possibility (by which time the AM peak hour demand was forecast to reach 27 trips and the PM peak hour would be 18 trips)[21].

It is notable that the pedestrian demand assumptions imply no latent demand in the base year (2012). This may be a unduly conservative assumption given that a substantially higher quality facility (e.g. pedestrian operated signals or grade-separated crossing) would likely encourage additional walking trips almost immediately. Even a small induced demand, say of four new walking trips in the peak hours, would effectively double the initial demand. Furthermore, if growth were assumed to occur linearly off this higher opening year demand the pedestrian demand would reach much higher levels, and at least four years sooner, than were forecast in the workbook.

While not directly related to pedestrian demand forecasting, the motor traffic volume forecasts in the workbook appear also to have been underestimated in retrospect; the workbook assumed peak hour growth of 15% between 2012 and 2017, and 31% between 2012 and 2022. Using the observed AADT traffic volumes between 2011 and 2018 the actual growth to 2017 was 31% and the estimated growth to 2020 is closer to 103%. Had this additional vehicle growth been forecast, along with assumptions about latent pedestrian demand, the workbook would have recommended a crossing facility much earlier (if not immediately).

Subsequent analysis undertaken by TMR suggested that pedestrian facilities would cost from around $330,000 for a pedestrian refuge through to $1.3 m for intersection

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[21] The more recent Australasian Pedestrian Crossing Facility Selection Tool (Austroads 2019) produces similar results insofar as it suggests only a median refuge or grade separation (signalisation is not recommended as the speed limit is >75 km/h).

signalisation and $2.4 m to $2.9 m for a grade separated crossing.  Ultimately, a pedestrian refuge was installed between April 2015 and June 2016 (Figure 5.2).

#### 5.1.1.3 Benefits

In retrospect, a pedestrian demand forecast that accounted for latent demand *and* motor vehicle traffic growth assumptions significantly higher than in the initial analysis could have been justified and may have led either to (a) earlier installation of the pedestrian refuge, or (b) the installation of a higher standard pedestrian facility.

- **Figure 5.1: Bundaberg Ring Road / Kepnock Road (image: Nearmap Pty Ltd)**

- **Figure 5.2: Pedestrian refuge (image: Google Streetview)**

### 5.1.2 Clontarf Pedestrian Operated Signals

#### *5.1.2.1 Context*

Hornibrook Esplanade runs along the foreshore in Clontarf and has 20,000 vpd across four lanes with a posted speed limit of 60 km/h. There is a park and footpath running along the foreshore and buildings on the inland side of the road consist of a mix of low density residential, retail and multi-storey apartment developments. The lots along the Esplanade are progressively being developed such that the population density and active street frontages are increasing. An example includes the construction of an apartment building at 80 Hornibrook Esplanade in 2013 that consists of residential apartments with ground-level retail including a fast food restaurant (Figure 5.4). The resident population within a quadrant in the vicinity of the development has growth from 437 to 648 residents (48%) between 2011 and 2016 (ABS 2017). There have been two Police-recorded crashes involving pedestrians in the past ten years along this section of Hornibrook Esplanade, one of which required hospitalisation of the pedestrian.

■ **Figure 5.3: Hornibrook Esplanade, population within area in red has growth 48% between 2011 and 2016 (image: Nearmap Pty Ltd)**

Pedestrian operated signals with a kerb outstand were installed in early 2019. Prior to the construction of these signals the nearest controlled crossing of the roadway was 400 m further south at the intersection with Elizabeth Avenue.

- **Figure 5.4: Pedestrian operated signals near 80 Hornibrook Esplanade, Clontarf (image: Google Streetview)**

Intuitively, there would be expected to be significant demand for pedestrian movements across this roadway given:

- the attractions of the foreshore, including the nearby park, foreshore path and beach
- the presence of a growing resident population to the immediate west of the esplanade, and
- the retail businesses operating from the ground level of the buildings along the road.

Pedestrian signals were installed by TMR some years after the development at 80 Hornibrook Esplanade was installed, and entirely at TMR's expense.

#### *5.1.2.2 Demand forecasts*

No pedestrian forecasts were used in the justification of the signal installation. Instead, the justification was based on the qualitative need for improving the safety for pedestrians crossing the road in the vicinity of this location.

#### *5.1.2.3 Benefits*

The absence of demand forecasts, or a robust methodology to doing so, precluded consideration of using the development application process as a means to fund the crossing. Moreover, it was difficult to make the case for funding the crossing (irrespective of the funding source) without quantitative forecasts – and indeed to be able to prioritise this location over numerus others which could have a similar qualitative justification.

However, it would have assisted decision making around the crossing to have had reasonable demand forecasts upon which to assess the merit of the crossing. Moreover, in the case of significant developments such as that at 80 Hornibrook Esplanade it is noted that the guidance on traffic impact assessment (TMR 2018) that is used as part of the development application process offers no guidance on forecasting pedestrian demand and so it is difficult to support a case for developer contributions to the provision of pedestrian facilities.

### 5.1.3 Queen's Wharf

#### *5.1.3.1 Context*

The Queen's Wharf development is a major brownfield development in the Brisbane CBD consisting of casino, retail, hotel and residential uses. The site abuts the Brisbane River and has both the Riverside Expressway and Bicentennial Bikeway running across the site. The Priority Development Area (PDA) scheme overlay for the area identifies several requirements on pedestrian movement, specifically (TTM 2017):

- Improve connections between the river and the rest of the CBD, including the Queen Street Mall
- Improving connections between Queen Street and Parliament House and the City Botanical Gardens
- Creating a network of cross block links
- Strengthening links along the river front between Victoria Bridge and Goodwill Bridge
- Supporting a navigable, equitable and legible cross river connection to Southbank.

The development includes a new pedestrian bridge from the site across the river to Southbank.

WSP conducted a pedestrian analysis on behalf of TTM and the development proponent that consists of both static and dynamic components (TTM 2017). The static component refers to the pedestrian demand forecasting aspects while the dynamic analysis involved crowd modelling; only the former is considered in this review.

#### *5.1.3.2 Demand forecasts*

A sketch planning method was used to determine the likely pedestrian demands from the development and then performance was assessed using Fruin's level of service methodology (Fruin 1971). The procedure was as follows:

- Short-period pedestrian counts were obtained at locations throughout the development area in 2016
- Trip generation rates for the Queens's Wharf development were obtained from empirical data from various sources[22]:
    - Residences (apartments) – RMS (2013a)
    - Hotel – KPMG hotel survey, source unknown
    - Retail – Halcrow (2011) for RMS
    - Restaurants – unstated

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[22] It is not stated what vehicle occupancy is assumed in converting the vehicle trip rates in these sources to person trips.

  - Casino– based on surveys of Las Vegas casinos (Ackeret and Hosea 1992)
- Walking mode shares were assumed to be 50% for visitors and residents based on analysis of the Victorian Integrated Survey of Transport and Activity (VISTA) data for Melbourne[23]. All employees in the area are assumed to arrive by foot, either by taking public transport or car but parking outside the development area.
- Trip distribution:
  - Travel zones were defined down to the level of each building entry and then linked to ten external zones (Figure 5.5) manually; no gravity model was applied.
- Assignment:
  - A maximum of two routes between each origin-destination pair were assumed; where there were two routes the demand was split evenly between the two routes
  - It is arbitrarily assumed that 40% of pedestrians currently using the Victoria Bridge will divert to using the new pedestrian bridge, as will 20% of pedestrian demand to/from a new development at 1 William Street (this project is committed but outside the Queen's Wharf development).

■ **Figure 5.5: Queen's Wharf zone system**

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[23] Separately, the TTM report also analyses census and SEQTS surveys for inner Brisbane and notes that around 50% of trips from or to the CBD and Spring Hill were by walking.

#### *5.1.3.3 Benefits*

The demand forecasts provided guidance to the developer and government on the likely deterioration in level of service that would occur on footpaths and at intersections in the vicinity of the development. Moreover, the WSP analysis made recommendations for widening pedestrian crossings at William Street at Margaret Street, and at William Street and Elizabeth Street as these intersections were forecast to experience the most significant deterioration in level of service. However, it is noted that the pedestrian trip generation assumptions are from contexts which may vary markedly from the Queen's Wharf site and the forecast demand at specific locations will be very sensitive to the trip distribution assumptions.

## 5.2 Australia

### 5.2.1 Major central city development: Bligh Street, Sydney

#### *5.2.1.1 Context*

The proposed redeveloped of 4-6 Bligh Street in the Sydney CBD consists of a 55-storey hotel and mixed-use tenancy. As part of the development application process AECOM (2018) prepared a pedestrian assessment study to consider the net impact of the development in 2026 with- and without the development.

#### *5.2.1.2 Demand forecasts*

The forecasting procedure followed a sketch plan procedure:

1. Existing pedestrian demands were obtained from counts on one non-holiday weekday during peak periods (7 – 10 am, 12 – 3 pm, 4 – 7 pm) on the footpath immediately in front of the development site and at the two nearest signalised intersections.
2. Two demand forecasts were developed for 2026:
    a. No development: background demand growth, including the future Sydney Metro station nearby, but no development at Bligh Street
    b. Development: as above but with the development at Bligh Street
3. Background demand growth was assumed to increase linearly with employment growth in the travel zone, which was forecast to be 10.5% by the NSW Bureau of Transport Statistics (this growth factor was applied to all movements except those in- and out of the development).
4. Pedestrian demand attributable to the new Sydney Metro station were estimated from forecasts prepared separately for the Sydney Metro Environmental Impact Assessment (EIA). These AM and PM peak volumes were extrapolated to the lunchtime peak period using existing ticketing data for the nearby Martin Place station.

5. Pedestrian traffic generated by the development were estimated from trip generation rates in TRICS[24] for food and beverage and hotel areas, and from local trip rates for the office component (GTA Consultants 2010). These trip generation sources are for all-mode trips; the inference was made that all these trips would be made by walking (i.e. that there is negligible car parking in the building).
6. Trip distribution for the Sydney Metro generated traffic was as per the EIA, with other trips distributed in the same proportions as observed in the counts. Trips generated by the developed are split evenly onto the footpath between the north and south directions for the food and beverage and hotel spaces, and according to the surveys for the office spaces.
7. Performance was measured using Fruin's (1971) level of service and Transport for London's Pedestrian Comfort Level (2019) for footpaths and intersections. Both measures indicated a significant deterioration of level of service would occur between 2017 and 2026 but that this deterioration would mainly be due to pedestrian movements introduced by Sydney Metro. The effect of the development was, in most cases, negligible and at a few locations reduced by Pedestrian Comfort Level by one level (e.g. B to B-).

#### *5.2.1.3 Benefits*

The demand forecasts indicated the effect of the proposed development on pedestrian level of service would be minor.

### 5.2.2 Parramatta Alfred Street pedestrian and cyclist bridge

#### *5.2.2.1 Context*

The Alfred Street bridge is a proposed pedestrian and cyclist bridge across the Parramatta River from Alfred Street east of the CBD to Baludarri Drive and Western Sydney University. The bridge would provide an alternative to the existing Gasworks Bridge (Macarthur Street) and James Ruse Drive road crossings of the river around 500 m to the west and east respectively of the proposed bridge. The proposed bridge would be 4.5 m wide and length of 197 m and would connect to the Parramatta Valley Cycleway on the north bank of the river. The Cycleway connects Westmead to Olympic Park. The area is rapidly undergoing major residential development that is expected to significantly increase local trips as well as providing developer contributions with which to partly fund the bridge. The under-construction Parramatta Light Rail will have a stop 100 m from the southern abutment of the bridge.

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[24] http://www.trics.org

#### 5.2.2.2 *Demand forecasts*

Pedestrian demand was forecast using a spreadsheet-based sketch planning method. The method was broadly as follows:

1. Trip Generation
    i. Demographic data (population and employment) from TfNSW's Transport Performance and Analytics standard land use forecasts (LU16)
    ii. Trip generation rates from the Sydney Household Travel Survey data for five purposes (home based work, home based education, home based shopping and personal business, home based recreation and non-home based and work-based work)
2. Mode split
    i. Mode share by trip purpose was obtained from the Sydney Household Travel Survey data; 37% of recreation trips were by walking with low walking shares for other purposes
    ii. Mode share was benchmarked against inner Melbourne journeys to work (census) data near a tram route; zones within 800 m of the proposed tram stop or major attractors had their non-recreational mode shares adjusted up to 30%, walking mode shares farther than 800 m but less than 1,200 m from the bridge for non-recreation purposes were increased by 20% compared to the HTS
3. Trip distribution
    i. A matrix of walking distances was constructed for each zone pair using Google Maps walk distances, and for the project case to the bridge abutment plus the length of the bridge.
    ii. Walk trips from each zone for each trip purpose were assigned to the nearest zone with that type of attractor on an all-or-nothing basis (a gravity model was not used as employment forecasts were not available by sector at the travel zone level)
4. Trip assignment
    i. Trips were assigned to the shortest route; no walking link quality attribute was used
    ii. Growth factors are applied to external (regional) trips based on demographics
    iii. Local and regional trips are summed to derive design volumes on bridge and approach links.

Walking catchments to heavy and light rail stations were assumed to have an average catchment of 800 m up to a maximum of 1,200 m where network quality was high. Primary, secondary and tertiary catchments were determined to travel zone boundaries:

- primary catchments were within around 800 m of the bridge and were stopped at major barriers to movement such as major roadways, and
- secondary catchments are beyond the primary catchment to a radius of around 1,200 m

To accommodate induced demand an uplift of 20% was applied to trips using the bridge. This assumption was derived from the worked example accompanying the ATAP guidelines (TIC 2019). Different annualisation factors were applied for transport and recreation trips in accordance with the ATAP guidance (TIC 2016).

The demand forecasts suggest pedestrian demand in the opening year of 2021 of 12,200 increasing to 21,600 in 2056.

#### *5.2.2.3 Benefits*

The demand forecasts were used as inputs to the cost-benefit analysis, which was undertaken using Australian Transport Assessment and Planning guidelines and parameter values (TIC 2016). The resulting BCR for the central case was above four, providing strong evidence to support the investment. Half of benefits (51%) were estimated to accrue from travel time savings following by 25% from safety and a further 13% from health benefits.

### 5.2.3 Parramatta Escarpment Boardwalk

#### *5.2.3.1 Context*

The escarpment boardwalk is a proposed connection between Gasworks Bridge (Macarthur Street) and the Charles Street Weir along the Parramatta River tot the immediate east of the Parramatta CBD. The 500 m connection will complete a missing link between existing sections of shared path that form the Parramatta Valley Cycleway. The estimated project cost is in excess of $10 m. Currently path users are required to take a circuitous route involving two at-grade road crossings and/or sub-standard paths to connect between the two sections of existing shared path and are subject to path gradients of up to 30%. A raised pedestrian crossing is provided across Macarthur Street, but this leads to motorist delays on what is the inner ring road around the Parramatta CBD.

#### *5.2.3.2 Demand forecasts*

Demand forecasts were developed to assist in the business case development, and particularly the cost-benefit analysis. Background population, employment and tertiary student forecasts from TfNSW were used to extrapolate existing measured demand from permanent counters near the missing link to a forecast year of 2036. Assumptions were made about the user proportions by weekday AM, midday and PM periods, and on weekends for the three user classes (resident, employee and tertiary student). Arbitrary assumptions were made about the catchment, with the immediate area of Parramatta assumed to generate 8% of walking trips, followed by North Parramatta (10%), Westmead Health and Rydalmere Education (2% each). Walking mode share in the wider area was assumed to grow from 9% to 19% between 2016 and 2056 based on wider strategic network modelling (the Sydney STM). In addition, an uplift of 10% was assumed to account for the added attraction of the route as it completes a missing link. The details of the modelling process are not described in the business case.

The model forecast slightly more than a doubling of pedestrian demand between 2016 and 2036 with the project. The business case does not specify whether the benefits were assumed to apply to *all* growth to 2036 or just the project-attributable growth. That is, the demand attributable to the project is the *difference* between the 2036 demand *with* and *without* the project (i.e. the Do Something and Do Minimum).

#### *5.2.3.3 Benefits*

The demand forecasts were instrumental in the development of the cost-benefit analysis and for the subsequent funding commitment to construct the facility.

The cost-benefit analysis suggested that 56% of the benefits were attributable to health benefits to pedestrians and cyclists, 25% to mode shift savings[25] and 15% to travel time savings. Safety benefits (1.4%) are a small proportion of the forecast benefit stream. The major benefit streams are all highly dependent on (a) the overall pedestrian demand forecasts, and (b) whether these trips are diverted from other routes, mode shifted or induced. In the case of the former group there would be expected to be no health benefit, and indeed in theory there could be a health disbenefit as existing pedestrians would be presented with a shorter route with fewer hills. Instead, the health benefits will accrue to those who shift from motorised modes and all-new walking trips (i.e. induced). For this type of cost-benefit analysis it is essential therefore that demand forecasts not only provide an overall estimate of demand but also split this demand into three groups:

- **Reassigned:** pedestrians who would have walked irrespective of the project, but have changed their route to use the project
- **Mode shift:** car or public transport users who shift instead to walking as a result of the project
- **Induced:** all-new walking trips generated because of the project (these would be expected to be recreational trips).

It is understood the 2036 pedestrian forecasts were achieved in 2017, or within a year of the base year 2016 counts, and before the project had even been built. This suggests the demand was massively underestimated, and also points to the challenges of estimating demand when the baseline magnitude of demand is low – that is, small absolute changes to small numbers result in very large proportional changes.

### 5.2.4 Sydney CBD and South East Light Rail

#### *5.2.4.1 Context*

The Sydney CBD and South East Light Rail connects the CBD to Randwick and Kingsford. The Public Transport Project Model (PTPM) was developed to forecast demand for this and

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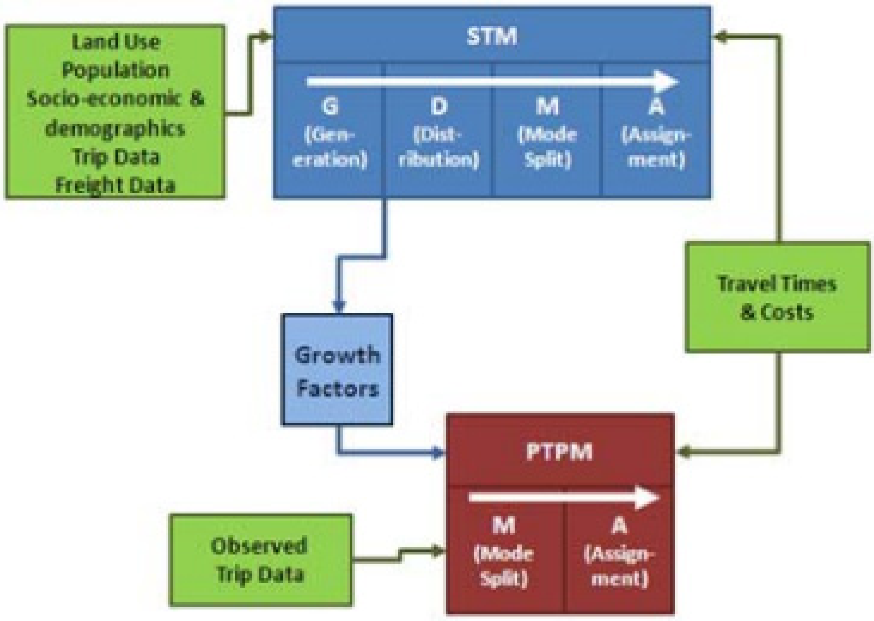
[25] While not stated in the business case, it is assumed this refers to vehicle operating cost savings by those switching from car to bicycle or walk, and fare savings for those switching from public transport.

other public transport projects in Sydney. The present case study is based on the review by Douglas *et. al*. (2019) of methods to estimate the patronage uplift that may occur as a result of walking trips diverting to light rail. The PTPM model is insensitive to intrazonal walk-to-PT movements; the concern being that the demand forecasts for the light rail may underestimate total demand by failing to account for these trips. It is reiterated that the issue here is not forecasting walking trips to or from light rail stops; these are accounted for in the PTPM model already (albeit without considering the walking infrastructure quality).

### 5.2.4.2 Demand forecasts

The PTPM model is a multimodal (rail, bus, tram, ferry and car/taxi), incremental model that pivots off observed trip matrices. The Sydney Strategic Travel Model (STM) provides the exogenous population and land use growth factors to PTPM as well as the skims[26] (Figure 5.6). The model forecasts for the AM peak weekday period and is trip-based.



■ **Figure 5.6: Sydney Public Transport Project Model structure (Douglas, Bradley, and Jones 2019)**

The model does not forecast diversion from walking to public transport (Douglas, Bradley, and Jones 2019). That is, it does not consider the additional light rail patronage that may occur as a result of pedestrians choosing to take the light rail instead of walking. As a workaround Douglas *et. al.* (2019) proposed two alternatives:

1. Apply a walking diversion trip factor based on either:
    a. before-after surveys of existing tram projects

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[26] "Skims" in this context are matrices with the generalised time or distance "cost" between each origin-destination pair.

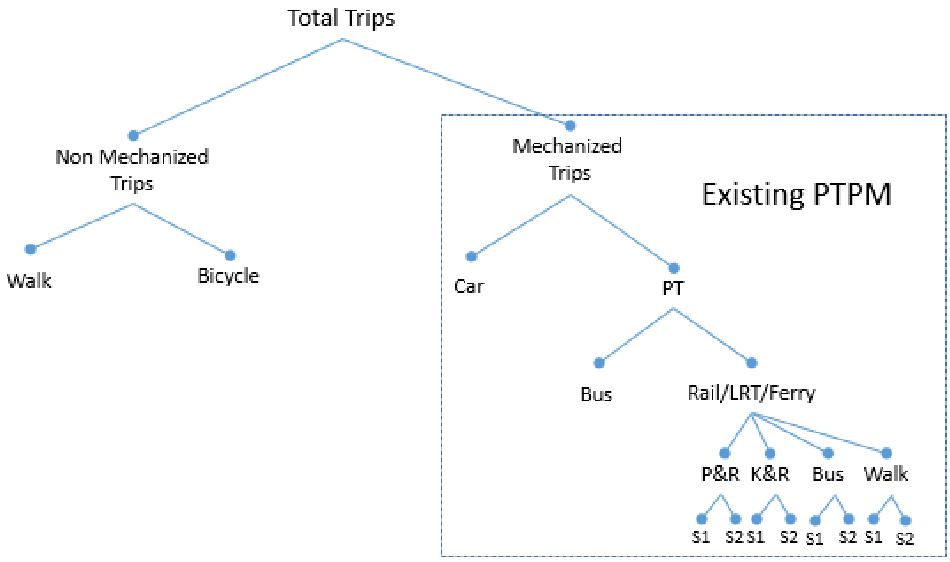
   b. Apply a walking diversion trip factor based on second-best alternative surveys (that is, surveys which ask respondents how they would have made their trip if the tram service was *not* available)

2. Forecasting walk diversion within the mode choice model, either as part of STM or PTPM using (ideally) an incremental mode choice model where the walk mode is either incorporated at the top of the mode choice hierarchy *or* in a standalone pairwise (walk vs PT) sub-model (Figure 5.7).

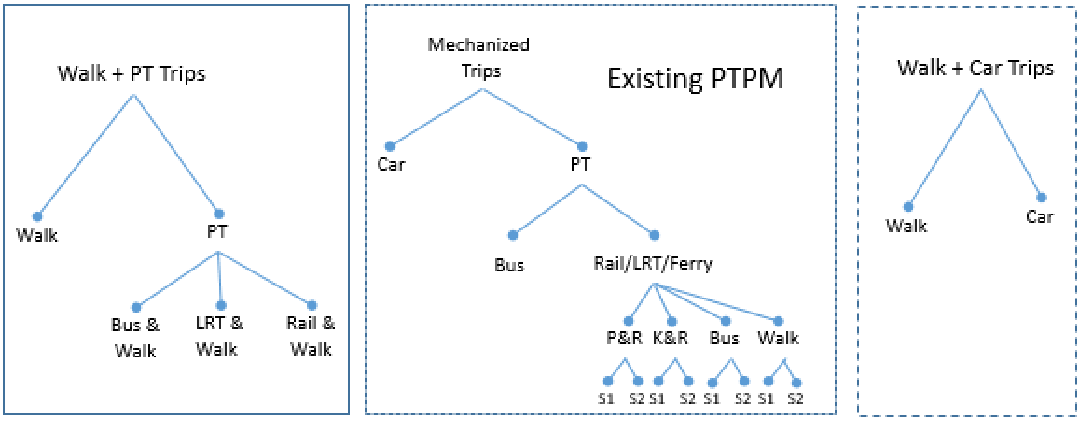
Where there is insufficient data on pre-existing walking trips in the corridor the authors recommend the use of a simple uplift factor. Should surveys be undertaken to obtain a base walking trip matrix the standalone pairwise model is recommended as walk-to-tram is likely to only occur to the nearest stop and so the added complexity of tram stop choice with walk / PT at the top of the hierarchy can be avoided.

#### *5.2.4.3 Benefits*

The methodology proposed by Douglas *et. al.* has not been implemented and so the benefits cannot be measured. However, this case study differs from the others considered in this review insofar as incorporating pedestrians in the model could conceivably be used to the benefit of the light rail project by increasing forecast demand. Such information may improve the business case and help ensure adequate capacity is provided.



(a) PTPM with walk/bicycle incorporated at the top of the mode choice hierarchy



(b) PTPM with a standalone pairwise sub-model

- **Figure 5.7: Proposed mode choice hierarchies to incorporate walking diversion to light rail in the PTPM model (Douglas, Bradley, and Jones 2019)**

### 5.2.5 Sydney Footpath Model

#### *5.2.5.1 Context*

The Sydney Footpath Model[27] is a bespoke model developed in the Python programming language by researchers at the University of New South Wales. The model is under development but has the ambition to be able to predict demand on footpath links so that it can measure the effect of new developments and walking links.

#### *5.2.5.2 Demand forecasts*

The model uses a traditional four-step transport modelling framework without the mode choice component as follows:

1. **Trip generation**:
    a. Simple commuting and office visitor trip generation based on zonal population (production) and total building floorplan area (attraction) using a model estimated for the City of London. Floorplan areas are for SA1 zones from NEXIS[28] and time-of-day splits are as per the London model.
    b. All-purposes determined from the Sydney activity-based model developed by UNSW; no further information on this model is available, although it is known to exclude tourism-related trip generations.
2. **Trip distribution:** gravity model based on network trip distances
    a. The footpath network use OpenStreetMap with centroids for each CBD block and connectors to each footpath (four for a conventional rectangular block).
    b. In the AM peak the gravity model is attraction constrained, with productions fixed to the railway stations and Circular Quay ferry terminal using Opal smartcard validation data.
    c. The destination choice model is estimated using data from the Victorian Integrated Survey of Travel Activity (VISTA) with variables of travel time, population density and employment density.
3. **Route choice:** models were estimated using walking trip data from smartphone (GPS) data on walking trips in the Sydney CBD (n = 1,250). Model variables were travel distance, time, number of turns and maximum slope.

The model could be considered a proof-of-concept. Among the limitations are:

- It is not clear that the London trip generation rates apply to the Sydney CBD.
- Footpaths between intersections are treated as a single link such that demand is constant on links between intersections; in reality demand will vary as pedestrian trips are generated and attracted by individual buildings within the block.

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[27] https://youtu.be/ljHk0Dy8nj0

[28] The National Exposure Information System (NEXIS) is a spatial database maintained by Geoscience Australia: https://www.ga.gov.au/scientific-topics/community-safety/risk-and-impact/nexis.

- The route choice model does not account for footpath quality or width.
- In the absence of a mode choice model there is no feedback between footpath quality and pedestrian demand; that is, induced demand cannot be modelled.
- The model has not been calibrated or validated. Intuitively the parameter for number of turns in the route choice model seems plausible (each turn is equivalent to 15 seconds of walking time) but the maximum slope parameter is equivalent to 8.4 minutes; that is, an increase in *maximum* slope of 1° (1.8%) is perceived by pedestrians as being equivalent to an additional walking time of 8.4 minutes; this feels high.

#### *5.2.5.3 Benefits*

If the model were validated and based on detailed data the proponents suggest it could be useful predict demand on footpath links subject to new land uses or disruptions such as construction-related footpath closures. However, the model is ultimately limited by the absence of data on walking network quality and existing pedestrian demand in much the same way as other similar models developed elsewhere in Australia and overseas.

## 5.3 Overseas

### 5.3.1 East London River Crossing

#### *5.3.1.1 Context*

The proposed East London River Crossing was a proposed pedestrian and bicycle bridge across the River Thames in East London between Rotherhithe and Canary Wharf.

#### *5.3.1.2 Demand forecasts*

Pedestrian forecasts were developed using several independent methods (Transport for London 2017):

1. Strategic models: existing strategic transport models the London Transportation Studies (LTS) model and the Railplan public transport model.
2. Bespoke commuting model: a local-area gravity model; a major trip generator and attractor (a hotel) is treated separately. Model parameters were estimated from stated preference surveys with existing ferry users.
3. Mode shift from Jubilee line: stated preference and stated intentions survey with rail passengers travelling between Rotherhithe and Canary Wharf stations immediately to either side of the river.
4. Induced demand: Stated intentions survey with local residents that forecast just over one additional (induced) walking trip for every mode-shifted trip.

In their combined forecasts they assumed non-commuting trips change proportionally at the same rate as commuting trips estimated from the gravity model.

#### *5.3.1.3 Benefits*

The forecasts were used as part of the project business case development.  However, cost estimates were substantially higher than initially anticipated such that council has instead proposed a ferry service as a less capital-intensive alternative to a fixed link.

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