Department of Civil Engineering

Calibrating the Distance-Deterrence Function for the Perth Metropolitan Area

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Declaration

To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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Abstract

The Perth metropolitan area and its surrounding regions have been expanding rapidly in recent decades and it is expected that this growth will continue in the years to come. With this rapid growth and the resulting increase in population, consideration should be given to strategic planning and modelling for the future expansion of Perth. The accurate estimation of projected traffic volumes has always been a major concern for transport modellers and planners. Development of a reliable, strategic transport model depends significantly on the inputs data into the model and the calibrated parameters of the model to reflect the existing situation. Trip distribution is the second step in Four-Step Modelling, which is complex due to its behavioural nature. The Gravity Model is the most common method for trip distribution. The spatial separation between the Origin and Destination zones will be reflected in the Gravity Model by deterrence functions which provide an opportunity to include people's actual behaviour when choosing their destinations based on distance, time and cost of their journey. Deterrence functions play an important role for distribution of the trips within a study area and would simulate the trip distances, and therefore they should be calibrated for any particular strategic transport model to correctly reflect the actual trip behaviour within the modelling area. This study aims to review the most common deterrence functions and calibrate them for the work trips in the Perth metropolitan area based on information in the latest available household data by the Australian Bureau of Statistics (ABS) and Perth and Regions Travel Survey (PARTS) data from the Department of Planning Lands and Heritage (DoPLH). The main outcome of this study will be a distance deterrence function for the home-based work trips which is calibrated in consideration with the actual work trip information for the commuters in Perth. For developing the suitable distance deterrence function, three different and most common functions i.e. Exponential, Power and Gamma functions have been examined. According to number of different analysis presented in this thesis, it is established that the Gamma function is the most suitable method for calibrating the work trip distribution and can accurately replicate the actual distribution of work trips in Perth. As part of this study and to investigate the accuracy of the proposed deterrence function for distributing the work trips in the network, a four-step transport model has been developed for the Perth metropolitan area using EMME4 software.

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I would like to express my gratitude to all those who provided me with the possibility to complete this thesis. I owe my deepest gratitude to my research supervisor, Dr. Amin Chegenizadeh, and my co-supervisor, Professor Hamid Nikraz, for their valuable supervision and support. Their guidance aided me to comprehend and to develop this research topic.

I greatly appreciate the help provided by Transcore Pty Ltd, who gave me the opportunity to use the EMME modelling software as part of this thesis. I also would like to thank the Department of Planning, Lands and Heritage, Western Australia, the Australian Bureau of Statistics and Main Roads Western Australia who provided me with detailed and valuable information for my research.

To my parents and my love, who have inspired my life in all manner,

for their continuous support which has helped me to pursue my higher education.

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Nomenclature

ABS	Australian Bureau of Statistics
Ai	Number of trips attracted to zone j
Aimsun	Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks
AWD	Average Weekday
CBD	Central Business District
CPM	City of Perth Model
DF	Deterrence Function
Dij	Distance between zone i and zone j
DoPLH	Department of Planning, Lands and Heritage
DoS	Degree of Saturation
EMME	Equilibrium Model/Multimodal Equilibrium
Fij	Friction factors between zones i and j
FSM	Four-Step Modelling
GC	Generalised Cost
GFA	Gross Floor Area (m2)
GM	Gravity Model
ITE	Institute of Transportation Engineers
LoS	Level of Service
MB	Mesh Blocks
MRWA	Main Roads Western Australia
NHB	Non-home-based
NLA	Net Lettable Area (m2)
OD	Origin and Destination

PARTS	Perth and Regions Travel Survey
Pi	Number of trips produced by zone i
RMSE	Root Mean Square Error
ROM	Regional Operational Model
SA	Statistical Area
SD	Standard Deviation
STEM	Strategic Transport Evaluation Model
Tij	Number of trips produced in zone i and attracted to zone j
VPD	Vehicles per day
WA	Western Australia

1 INTRODUCTION AND BACKGROUND

1.1 Introduction

This research has led to the establishment of a distance-deterrence function for work trips in the Perth metropolitan area. The importance of deterrence function is to better calibrate the trip distribution and to account for people's actual travel behaviour.

As part of this research, a simple daily strategic transport model was developed using EMME software to primarily assess the performance of the distance-deterrence function proposed for the work trips (INRO 2017).

Input to the EMME software was provided by way of information from a number of Australian governmental agencies as follows:

- The zoning system for the strategic model was in accordance with Australian Bureau of Statistics (ABS) geographical boundaries for Statistical Areas Level 2 (SA2).
- The road network coded into the model was based on Main Roads Western Australia (MRWA) information for regional roads.
- The model inputs (i.e. the land uses) were provided by both the ABS and Department of Planning, Lands and Heritage (DoPLH).

The calibration of the daily model was based on the targeted traffic volumes on the major roads within the Perth metropolitan area. For a more robust assessment, and as the traffic interaction between the Perth metropolitan area and Peel region is reasonably high, the extent of the model also covers the Peel region.

1.2 Background

A transport model is a synthetic tool which considers and incorporates the relationship between the road network and land uses within the intended area of modelling. It can analyse the impacts of existing infrastructure (i.e. roads and means of accesses with respect to the land use data).

Transport modelling provides numerous benefits in traffic and the transportation industry, and can be used as a basis for future planning purposes.

A calibrated transport model is a reliable tool which can be used to indicate future travel demands with respect to future land uses and infrastructure.

Having a sense of future traffic volumes on existing and proposed road networks is an essential step to making important decisions with regards to future requirements, especially for urban areas.

The forecasted traffic volumes will dictate the need for any potential upgrades on the existing infrastructure, or indicates whether any additional infrastructure is required.

The significance of transport modelling is briefly explained as follows:

- it provides an analytical relationship between the existing demand and the existing land uses
- it provides a robust assessment for future demands and requirements of any future civil works
- it provides town planners and civil engineers with an opportunity to cost-estimate significant projects.

A transport model consists of the following features:

- a demand model (the traditional demand model is the Four-Step Modelling (FSM) which is the basis of this research)
- a means of access model (motorised vehicle, public transport, heavy vehicle freight links, rails and ferries etc.)
- an Assignment Model.

Transport modelling is widely used all around the world. It is available for use from micro levels to strategic levels, and can be used for decision-making purposes by governments and/or the private sector.

It is normal practice to establish a transport model for large cities and to use that as a tool for predicting future traffic volumes as a result of growth in the population.

Trip distribution is one of the most important steps for the modelling, as errors which may occur during the trip-distribution step will be propagated throughout the model and result in a less reliable outcome. Therefore, it is very important to give consideration to this step and to try to calibrate the trip distribution as accurately as possible based on the existing demands.

1.3 Objectives

This research aims to investigate distance-deterrence functions and calibrate the required parameters for work trips within the Perth metropolitan area.

Accordingly, the objectives of this research can be summarised as follows:

- to determine whether any possible similar study by other researchers around the world has been undertaken, through a comprehensive Literature Review including library and internet searches, and direct contact with local and international people who are working in this field of research
- to investigate and calibrate different deterrence functions for the Perth metropolitan area based on the information obtained from the DoPLH, namely the Perth and Regional Travel Survey (PARTS) data, and the household data provided by the ABS
- to develop a transport model for the Perth metropolitan area
- to undertake programming with SPSS software for calibration and fitting the best function for work trips in accordance with the actual travel survey data
- to investigate the performance of the calibrated deterrence functions through the developed strategic transport model for the Perth metropolitan area and discuss the modelling outcomes.

1.4 Research Significance

This research study is unique in its various aspects, and a quantity of new knowledge has been developed during the course of this work.

It is known that developing a reliable traffic model which can replicate the existing traffic pattern is indispensable. Such exercises have been undertaken in different parts of the world and have always been a main area of focus in terms of future planning, infrastructure provision and traffic-management decisions for urban developments. The new knowledge developed through this research study is multi-fold, some of which is presented here:

- Travel demand forecast is an essential element for transportation planning to evaluate future needs of an urban area. A robust and efficient technique is required to predict the patterns of trips in the future so that the desired outcomes and impacts can be achieved and anticipated.
- The ultimate output of this study is a recommended distance-deterrence function for work trips in the Perth metropolitan area which could be used to reflect the existing work traffic pattern and trip length. This model can be used for short-term, medium-term and long-term planning, meaning that once the model is calibrated for the existing traffic patterns, it can be used as a reliable tool which is capable of forecasting the traffic patterns and traffic volumes considering future developments and road networks.
- This ability can assist future planning and cost management, and is closely associated with human lifestyle which, for a developing city such as Perth, can be considered an essential tool.
- This research will propose calibrated deterrence function for the Perth metropolitan area based on the latest available household data which is used for the existing transport model developed for Perth.
- The results of this research can assist future students or consultants to use the recommendations of this study to establish strategic models and sub-area models that might be developed for different parts of Perth.

1.5 Thesis Structure

The thesis comprises 10 chapters.

Chapter 1 is the introduction and background. This chapter describes the objectives, briefly reviews the methodology, and discusses the significance of the research.

Chapter 2 consists of a comprehensive literature review on the available research in the field of trip-distribution estimation and transportation modelling. Similar studies are reviewed and discussed in this chapter.

Chapter 3 briefly discusses different essential concepts discussed throughout the thesis; in particular, the concept of trip distribution and the application of the Gravity Model and its use in estimating the trip distribution.

In Chapter 4, the input information for the established transport model for the Base Year scenario (Year 2011) will be discussed in detail. The author's special appreciation for this chapter goes to the governmental agencies which have kindly provided the required information for this thesis.

Chapter 5 includes detailed discussion on trip-length calibration for work trips in the Perth metropolitan area. A detailed review and analysis on the actual trip-length information are provided in this chapter. A number of curve-fitting analyses based on three different deterrence functions are also undertaken in this chapter, and the results are discussed in detail.

Development of the EMME transportation model is discussed in Chapter 6. The application of FSM in preparation of the model, all the assumptions, and different modelling aspects are also included in this chapter. Traffic volume calibration analysis will also be discussed in this chapter.

Chapter 7 includes analysis based on the outcome of the EMME transportation model. The accuracy of the deterrence function proposed in Chapter 5 will be tested via the developed transport model, and the results of the analysis discussed and presented in this chapter.

Chapter 8 comprises more detailed analysis on a number of different origin destination zones to review the accuracy of the trip distribution in consideration of the proposed distance-deterrence function on a smaller scale. The application of model self-sufficiency for commuters to work in the Perth metropolitan area will also be discussed and presented in this chapter.

Chapter 9 includes detailed analysis on the application of river-crossing for work trip-makers. This chapter will conclude percentage estimations for the work trips commuted, using eight major bridges in Perth that cross the Swan River towards the northern and southern suburbs.

Chapter 10 draws together the conclusions of this work, and outlines recommendations for further research and studies in this area.

Substantial references used in this study are listed at the end of this thesis.

Appendixes provided at the end of this thesis include most of the raw information and data used for the analyses undertaken as part of this work, in particular the information which was used to develop the strategic transportation model for the Perth metropolitan area.

Also, at the end of each chapter, a summary section is provided, which outlines the key discussions outlined in that chapter.

2 LITERATURE REVIEW

A detailed and comprehensive review of the available literature in the area of traffic and transportation engineering, and in particular transportation modelling, will be presented in this chapter. The objective of the literature review is to establish the relevant work and research already undertaken in this area. The literature review will be presented in a hierarchical format. It will first start with a brief explanation of Macroscopic, Mesoscopic and Microscopic modelling. Secondly, it will focus on Macroscopic modelling at strategic levels, which is more relevant to the scope of this research study. Thirdly, the available literature on the concept of Four-Step Modelling (FSM) will be discussed with more consideration given to the second step, which is trip distribution. Trip distribution methods will then be further discussed, and the shortcomings of non-synthetic models will be acknowledged. The Gravity Model and its benefits will then be discussed in detail, and the application of deterrence function for trip-length calibration will also be discussed in detail.

Each section of this chapter aims to point out any existing similar work or research related to that section. In the last section, a table which contains the key literature discussed throughout the chapter is presented to provide opportunity for an at-a-glance review.

This author hereby acknowledges that all endeavours have been made to mention the owners of the copyright materials sourced in this chapter to the best extent of his knowledge.

2.1 Macroscopic, Mesoscopic and Microscopic Modelling

Travel demand forecasting, and short-term and long-term transportation modelling can be considered an indispensable area for research. This is because, for a developing area such as the Perth metropolitan area and regions, government policies are aimed towards increasing the population, which results in the significant requirement for accurate traffic projection, robust transportation planning and future road provisions.

Zhong and Lu (2012) state that there are two major approaches for demand forecasting. The first approach is the common FSM. The FSM approach has been used for many years by most researchers, and its uses are mainly for large-scale forecasting – **strategic transport modelling**. The second approach is known as the activity-based or **Microsimulation** method, which deals with the travel demand on finer and smaller scales. In recent years, another level of modelling has become quite popular (particularly in Australian industry), and in terms of scale and detail it lies between strategic modelling and Microsimulation modelling – it is known as **Mesoscopic modelling**.

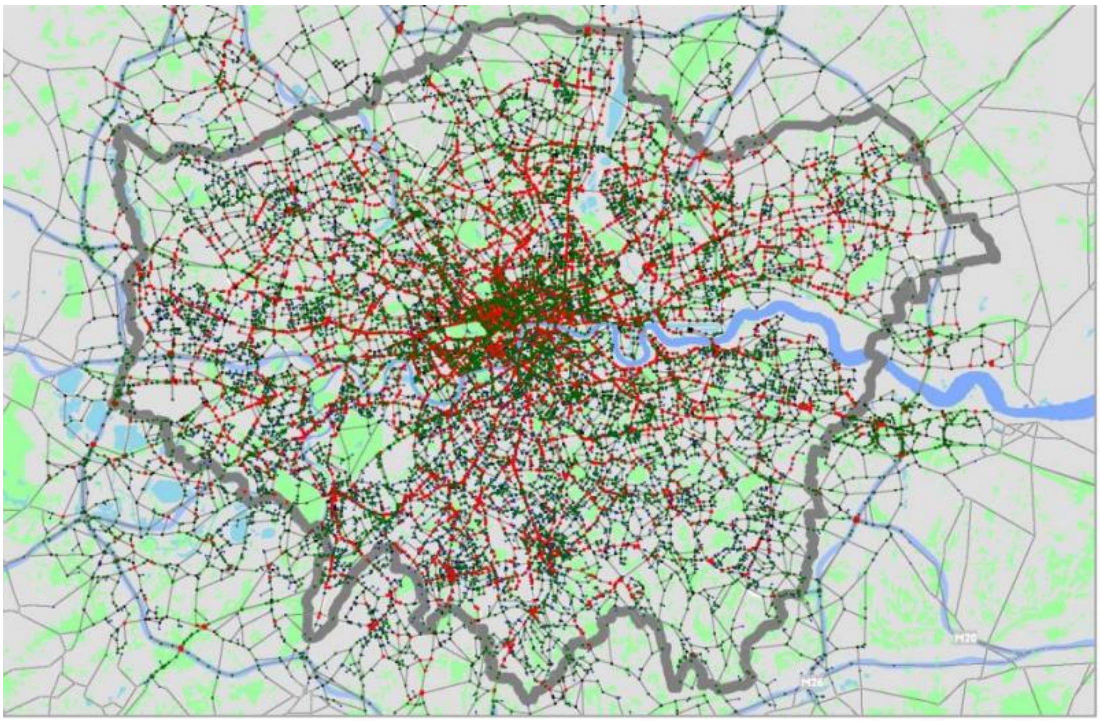
A brief review of the three levels of transportation modelling is provided in this chapter. However, as the focus of this thesis is on strategic modelling for the Perth metropolitan area, more weight and focus is placed on the strategic level by examining a number of previous research studies around this concept.

2.1.1 Macroscopic Modelling

Taplin, Taylor and Biermann (2014, 5-12) introduce Strategic (Macrosimulation) modelling as an Assignment Model, which is suitable at the strategic level and which is part of the traditional FSM normally used for large-scale areas. The strategic models are usually applied to 24-hour Origin and Destination (OD) matrices. In terms of the details, the strategic model works with major road networks with less road network and intersection details. It is important to note that the assignment methods used for macro models are normally based on static assignments, which do not take dynamic behavioural patterns into consideration. It is normal practice to develop a strategic transport model for large cities. This level of modelling requires detailed assessments of the land use and travel survey data, and is undertaken by a research team over a long period of time. These projects are normally requested and funded by governments, which usually employ an internal traffic and transportation team to assist with development of the model, and sometimes may hire an external consulting team to develop the model. In essence, this work requires substantial time and effort; however, the models developed as a result are an investment which can be utilised for different future strategic planning and traffic forecasting practices.

According to TfL Planning (Transport for London Planning) report *London's Strategic Transport Models* (2012), the strategic highway model which covers the whole of London, LoHAM (London Highway Assignment Model) was developed via SATURN software. The Base Year for the model's development was 2012, for which the model's inputs were available. As a result of developing the SATURN model, further future traffic studies for 2021, 2031 and 2041 were also carried out. A map showing the extent of the LoHAM model is shown in Figure 2.1.

Figure 2.1: Strategic transport model showing junctions in LoHAM



Source: (*London's Strategic Transport Models*, TfL 2016, 7)

Bliemer et al. (2013) review the use of strategic transport modelling and compare that with Microsimulation modelling. Their focus is upon the advantages of strategic models compared to Microsims; however, they propose a new assignment methodology which defers from the traditional static assignment introduced for macro models in the 1950s. The proposed assignment method as set out in their study is called 'quasi-dynamic model'. Although they agree that a macro model is designed to assess a large-scale area with less attention placed on dynamic features such as delays, turn counts and queue analysis, they did investigate a new Assignment Model to try to implement the dynamic features into macro models.

The researchers' proposal has been discussed and supported by investigating the accuracy of five critical aspects, which are as follows:

- realism of results
- robustness of results
- consistency of results
- reliability and accountability of results
- ease of use.

To support their proposal, they tested the proposed quasi-dynamic assignment in models prepared for four case studies in two cities in The Netherlands (Amsterdam and Rotterdam) and two cities in Australia (Sydney and Gold Coast) with the software package which the Assignment Model was implemented to, namely OmniTRANS. Their publication acknowledges that the focus of the study was to test the proposed assignment method and, as such, consideration has not been given to calibrating the models to reflect the existing traffic volumes on roads. The model network characteristics for each city are presented in Table 2.1.

Table 2.1: Modelling network characteristics

Network	Number of TAZs	Number of links	Number of nodes	Number of routes	Number of OD pairs	Number of vehicles	CPU time per iteration[3]
Amsterdam[1]	418	9,408	4,281	266,505	275,722	271,772	3 sec.
Rotterdam[1]	1,744	17,187	6,422	1,394,853	737,415	260,324	18 sec.
Gold Coast[2]	1,067	9,565	2,987	1,221,524	592,856	243,838	19 sec.
Sydney[2]	3,264	75,379	30,573	2,394,496	1,045,156	1,569,698	89 sec.

[1] Network and OD matrix kindly provided by Goudappel Coffeng BV, The Netherlands
[2] Network and OD matrix kindly provided by Veitch Lister Consulting Pty Ltd, Australia
[3] Using a notebook computer with Intel Core i7 @ 2.80Ghz running Windows 7

Source: (Bliemer et al. 2013)

Furthermore, the network of the roads subject to the modelling for all four cities is shown in Figure 2.2.

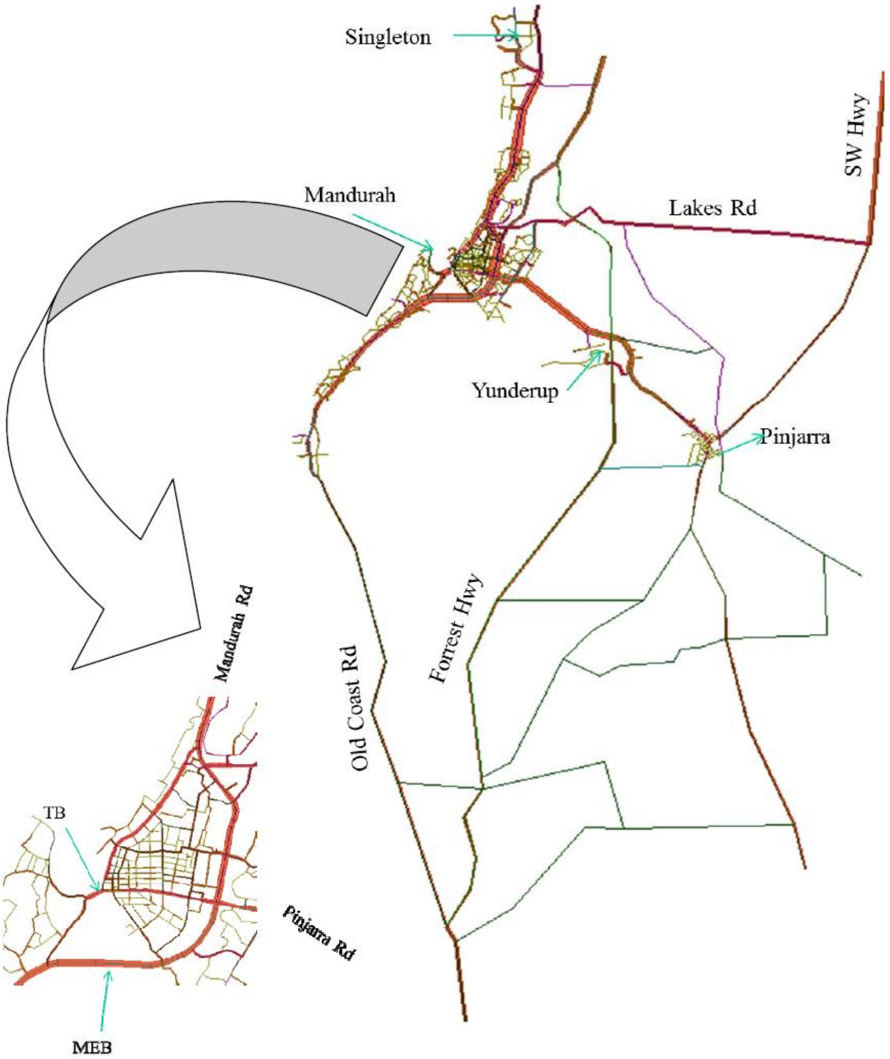
The accuracy of the proposed assignment was discussed by undertaking queue distance analysis for selected intersections. However, it would be creditable if the accuracy of the proposed assignment method were implemented in a pre-established calibrated transport model to try to investigate the outcome of the model, mainly with respect to the traffic volumes, and to compare the quasi-dynamic Assignment Model with the traditional static model.

Figure 2.2: Network coding

Source: (Bliemer et al. 2013)

Another example of strategic transport modelling can be found in Transcore's work undertaken on behalf of the City of Mandurah council for the entire Mandurah municipality in Western Australia (WA) (City of Mandurah 2012). The modelling exercise was based on EMME modelling software, which involves a static assignment of traffic. The modelling coverage comprised in the study included 38 residential zones, with further consideration given to coding the Central Business District (CBD). The extent of the modelling area is shown in Figure 2.3. As part of this work, the model was calibrated to replicate the existing traffic volumes on roads. The developed model is now used as an asset for the City of Mandurah to undertake additional modelling analysis and planning investigations for the future of Mandurah, with respect to potential population growth and changes to the infrastructure.

Figure 2.3: Mandurah strategic model, extent of the model



Source: City of Mandurah (2012)

The software packages which are commonly used for Macroscopic modelling at the strategic level are EMME, SATURN, PTV Visum, TransCAD and OmniTRANS.

2.1.2 Mesoscopic Modelling

The Transport Modelling website states: “Mesoscopic modelling allows a level of detail greater than a strategic model. All software houses recognised the need for a software package that sits between strategic and micro-simulation modelling capability” (2017).

Therefore, Mesoscopic models deal with transportation studies across a broader area compared to Microscopic studies and deal with transportation studies on smaller scales when comparing with Macroscopic studies. In other words, and according to the PTV Group website, when the modelling area is expanded to a higher level than Microsims there are normally a number of various routes from the OD zones for distribution (2017). This replicates the circumstance in which the modelling software would require distributing the traffic through a more complicated assignment to replicate the realistic traffic distribution. The concept of Mesoscopic modelling is newer than the other two levels of simulations but has rapidly become quite popular in recent years. The advantages of Mesoscopic models are related to the useful information they can provide considering a dynamic assignment. The inputs to the Mesoscopic models are normally extracted from the outputs of strategic models. The OD matrices extracted from a strategic model can be fed into a Meso model to be used for assigning the traffic within the network. By running the Meso model, the propagation of the queues within the modelled network area can be observed and assessed. Queue-length analysis is the main feature for calibrating such models. This author has recently been involved in two Mesoscopic modelling projects for the Bassendean Activity Centre redevelopment, in the Town of Bassendean, and the City of Karratha, both in WA.

The software packages which are commonly used for Mesoscopic modelling are SATURN, PTV Vissim, Aimsun and Dynameq.

2.1.3 Microscopic Modelling

Microsimulation modelling has been used from the early days of development of traffic modelling and analysis for urban areas (Akçelik and Besley, 2001). Microsimulation techniques, as it relates to traffic and transportation engineering, refers to a technique of modelling small-scale networks with dynamic traffic behaviours, and which is normally used for hourly traffic simulation and modelling. Simulating the network traffic for peak-hour situations is an important measure for urban planning, but at the same time it is a difficult procedure which involves complex assessments and analysis. A key feature of a successful Microsimulation outcome is to calibrate the dynamic aspects of the model, such as time, delay and queue-back analysis, in accordance with what is observed in the existing situation. The output of the Microsimulation will provide important information regarding the intersections' operational conditions such as level of service (LoS), queue back measurements and the degree of saturation (DoS) of the intersections.

An example of the use of Microsimulation modelling is included in the research carried out by Madi in 2016. The accuracy of the model calibration was based on the existing situation for one kilometre of an arterial corridor in Outley Road (A660), Leeds, in the United Kingdom (UK). An Aimsun Microsimulation model was developed for the AM/ Off-peak period as part of the study. The model calibration practice was undertaken in accordance with the actual dynamic statistics for two different options. Option A was based on speed, and Option B was based on acceleration. An additional analysis was also undertaken based on Aimsun – default dynamic values. Modelled car dynamic parameters for all three options are provided in Table 2.2.

Table 2.2: Car dynamic values used for model calibration

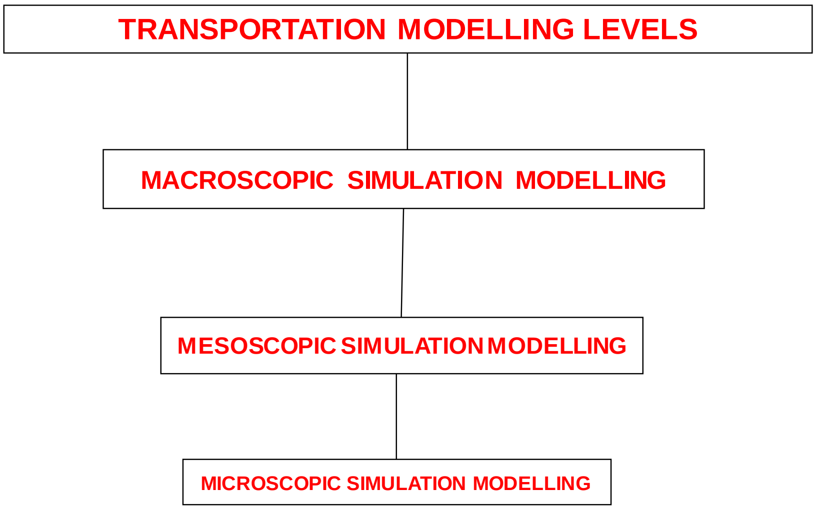
Parameter	Default Car Dynamics				Option-A				Option-B			
	Mean	Dev.	Min	Max	Mean	Dev.	Min	Max	Mean	Dev.	Min	Max
Max Desired Speed km/h	110	10	80	150	100	20	80	150	42	4	35	48
Max Acceleration m/s2	3.00	0.20	2.60	3.40	1.85	0.43	1.35	2.75	2.23	0.27	1.76	2.73
Normal Deceleration m/s2	4.00	0.25	3.50	4.50	5.00	0.50	4.00	6.00	1.61	0.18	1.25	1.86

Source: (Madi 2016)

The research concludes that the use of Aimsun default values could not represent people's actual travel behaviour in the study area, whereas Option B resulted in a reasonable calibration which could even reflect the emission-sensitive vehicle dynamics factors. This can be a good example for modellers to *not* rely on the software's default values in different circumstances, and that on-field actual travel behaviour should be the standard for undertaking such a micro-level assessment. That said, usage of software default values in such circumstances where acquisition of actual data is not possible might be the only possible option, but it is always a debatable industry practice.

Overall, the levels of transportation modelling are shown in Figure 2.4.

Figure 2.4: Transportation modelling levels

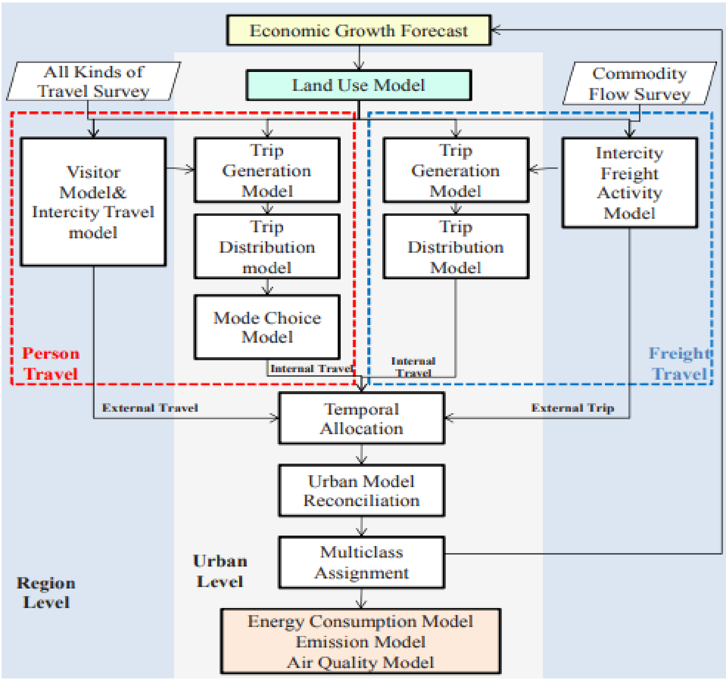


2.2 Four-Step Modelling

As part of the outcome of this research, a macro strategic model for the Perth metropolitan area is produced via EMME software, and as such, the rest of this literature review focuses mainly on this level of transportation modelling and the application of FSM for undertaking large-scale transportation modelling exercises. FSM is a highly reputable approach in transportation modelling, and its significance and usage are quite well-known both for industry practitioners and academic researchers. Furthermore, FSM in transportation modelling has always been a very interesting research area at academic levels, and researchers have conducted significant in-depth studies over the years to establish its importance and application.

Wang et al. (2013) discuss the significance of FSM and share the disadvantages of the existing urban transportation models in China, suggesting a framework to establish an integrated multimodal transportation model to follow the traditional FSM. The framework they propose is shown in Figure 2.5. The researchers recommend that an integrated model should be established for the urban areas in China, in accordance with the application of FSM so that it can be used for prospective planning for the urban areas.

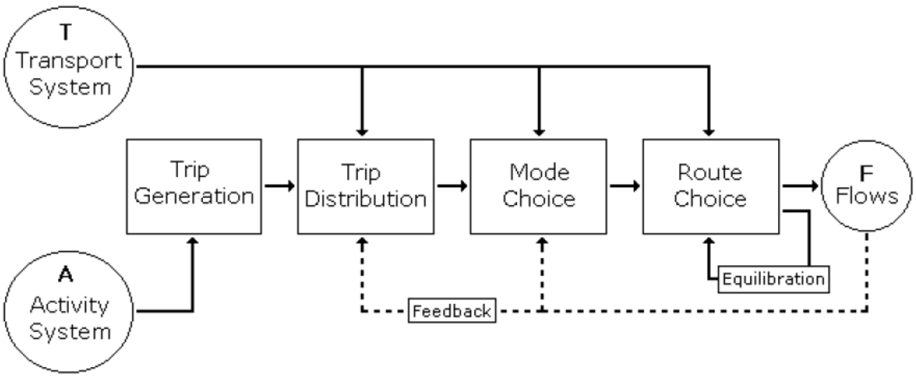
Figure 2.5: Integrated transportation model suggested by Wang et al. (2013)



Source: (Wang et al. 2013)

McNally (2007) has undertaken a comprehensive study on the concept of FSM, its input, output and the probable restrictions and problems. Figure 2.6 illustrates McNally's definition of FSM.

Figure 2.6: Four-Step Modelling diagram suggested by McNally (2007)



Source: (McNally 2007)

The flow chart provided in Figure 2.6 is explained in more detail as follows.

Trip-Generation step

As illustrated in Figure 2.6, the first step in FSM is the trip generation, which measures the total number of originated trips in the area intended for study/modelling. Trip generation can be defined as a process of estimating the total number of trips generated from an origin traffic zone. Estimating the trip generation for a specific area under study is a complicated process, but it can be practically undertaken by measuring the number of trips coming into and leaving that zone over a specific period of time; for example, 24 hours. This practice provides an accurate estimation of the trip generation for that traffic zone. Wu and Liu's (2014) research provides a comprehensive overview of different data collection methods from the conventional fixed-point sensors to the more recently introduced high-resolution, event-based data. Although these exercises result in an accurate estimation of the trip generation, it is considered an expensive practice and is not feasible for traffic zones with larger scales. Therefore, other policies and guidelines are commonly being used to estimate trip generation. Some of these common guidelines can be found in Mousavi, Bunker and Lee (2012). In Australia, the most common guideline for trip-generation estimation is the *RTA Guide to Traffic Generating Developments* (Roads and Maritime Services (NSW) 2002). This document provides hourly and daily trip rates which are based on average traffic surveys undertaken for different land uses. These trip generation rates provide a reasonable estimation of the traffic generation anticipated for each development. The trip rates indicated in the guide can be based on different criteria for each land use, such as floor areas. For commercial, retail and industrial land uses, for instance, the Gross Floor Area (GFA) of the development is considered for estimating the traffic generation based on the guide. The *RTA Guide* also provides recommendations on the parking requirements for different land uses, which are again based on actual parking surveys. Another international guideline for estimating the traffic generation of different land uses is the *Trip Generation Handbook*, which contains the standard guidelines for the United States (US) and includes a wide range of information for various land uses (ITE (Institute of Transportation Engineers 2014). The application of ITE guidelines are ubiquitous and result in a reasonably accurate estimation of traffic generation. Although traffic generating guidelines are still used for development applications and assessments, lately other methods of trip generation estimation have been reviewed and suggested, based on the latest technologies.

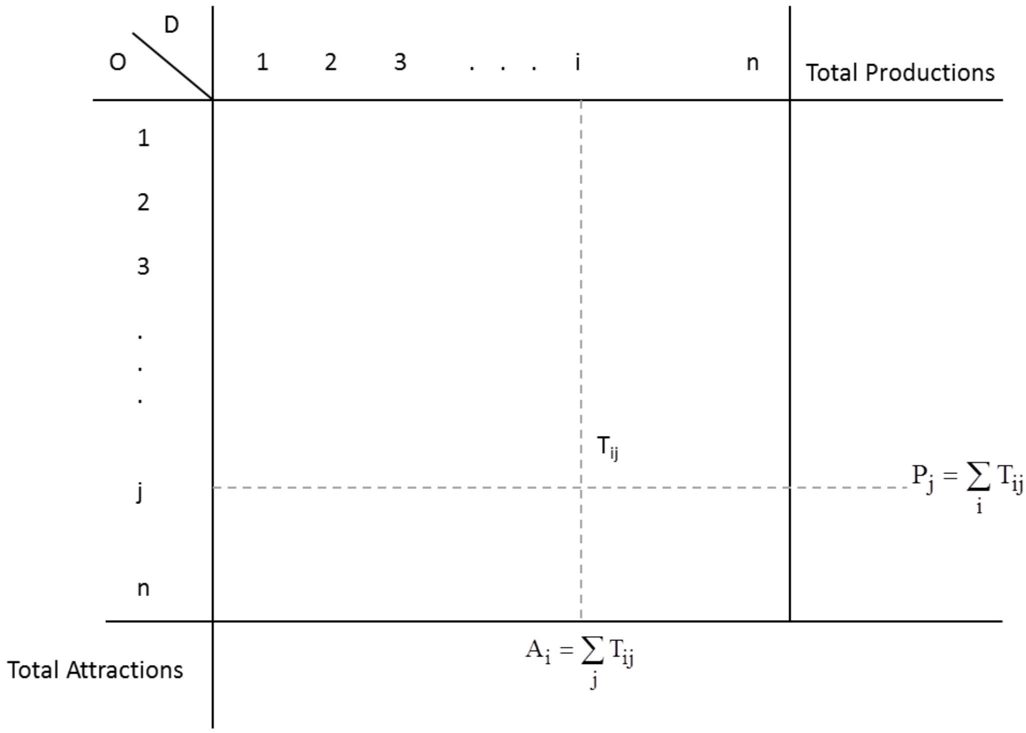
Bwambale, Choudhury and Hess (2017) discuss different ways of trip-generation estimation such as mathematical approaches and mobile phone passive methodology, which works with telephones to log the trip generation, and point out the limitations of this model. The researchers also propose a new way of trip generation estimation using the Hybrid Model, which works with Global System for Mobile Communications (GSM) data and Call Detail Record (CDR) data. In this model, the GSM records all the active intrusion detection systems in a study area to estimate the trip generation (Bwambale, Choudhury and Hess 2017). Usage of Bluetooth has also become popular in estimating trip generation. This method can also be used for undertaking OD surveys for a sub-sample; however, as this falls outside the scope of this research, it is not discussed in depth here.

Trip Distribution

Trip distribution is known as the second step in FSM. The purpose of the trip distribution is to estimate the trip linkages or interactions between the traffic zones for trip-makers (generators and attractors). The distribution of trips between traffic zones can be demonstrated by an OD matrix (as shown in Figure 2.7). Trip distribution follows the trip generation and distributes different generated trips from the generation zones onto attraction zones.

Note: As this research mainly focuses on the trip-distribution step out of all four steps in FSM, more emphasis is placed on trip distribution in this chapter, providing details on various concepts, along with highlighting previous research conducted.

Figure 2.7: OD matrix suggested by Rasouli (2014)



Source: (Rasouli 2014)

Growth factor methods and **synthetic methods** are two techniques for estimating trip distribution.

The growth factor in estimating trip distribution is related to the growth rates between the OD zones, which are more appropriate for short-term planning (Mathew and Rao 2006). Growth factor itself can be classified into four types. The first type is known as uniform growth factor and it is used where the available data for estimation of trip distribution is that of the growth rates between the generation and attraction zones. The second type is when there are multiple growth factors between the OD zones. This classification is known as the Doubly Constrained Growth Factor Model. Although the Growth Factor Model is easy to understand and preserves the observed travel pattern, it has some limitations too. The most important shortcoming for growth factor is the fact that this method is not able to demonstrate people's actual travel behaviour and hence may not be able to result in a robust assessment in complex situations. There are two other growth factor methods, namely the Fratar Model and Furness Model.

With reference to his report on trip-distribution techniques, Bhasker states that in the Fratar Model method, the total generated trips in each zone are distributed into the interzonal movements based on an initial approximation (2017). This initial approximation is dependent on the attractiveness of the destination zones. Once the first set of distributions is completed, the same procedure will be used again for the second iteration. This iterative procedure will continue again and again until the balancing numbers are derived. The Fratar method can be executed manually; however, it is not an appropriate approach for large-scale travel demand analysis.

The Furness Model works with an initial estimation of the total traffic generation and distribution for the OD zones. Thereafter, the distribution of the trips between the zones will commence by applying an initial growth factor in such a way that the row of the OD matrix terminates into the desired number of trips. The same exercise will again be conducted so that the desired number of trips for the column of the OD matrix is achieved. This iterative exercise will be undertaken repeatedly so that a rough satisfaction between the row and the column of the OD matrix is achieved.

The limitations of the Fratar and Furness models are that: 1) both require an initial trip distribution matrix; 2) if there is an error in the initial OD matrix the error will be magnified; 3) neither of these models can consider people's actual travel behaviour in distributing the traffic; 4) they do not account for travel costs or any other impediments of travel; and 5) they are both cost and time consuming since they require traffic surveys of OD matrices.

Synthetic models have been introduced for the trip-distribution step to bring the actual travel behaviour of commuters into the trip-distribution techniques. These models aim to discern the impediments of travel such as distance, time and costs, and apply them to trip distribution. Synthetic models are less expensive than Growth Factor models and can be used for larger-scale modelling. Another advantage of synthetic models is that their use can actually develop a model of Base Year, which can be used for future traffic predictions. Mekemson and Sinha (1979) conducted research on synthetic models for small urban areas in India with a population between 50,000 and 250,000. For the study, they employed different synthetic models to investigate the performance of each technique. The purpose of their research, as set out in the summary of this literature review in Table 2.3, is to eliminate the traffic-related surveys, which are considered an expensive and time-consuming process.

There are different synthetic models for distributing trips, as follows:

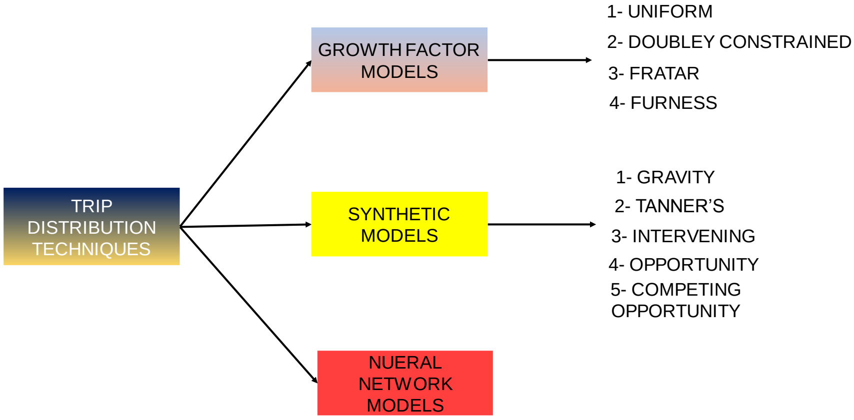
- Gravity Model
- Tanner's Model
- Intervening Opportunity Model
- Competing Opportunity Model.

Among all four above-mentioned models, the Gravity Model is the most well-known model for distributing trips and is the basis for developing the Perth metropolitan area as part of this research. Thorough discussion on the Gravity Model will be provided in this chapter and elsewhere within this thesis.

There are also other techniques for undertaking trip distribution, such as the Neural-Network technique, which falls outside the scope of this work.

Overall, the levels of transportation modelling are shown in Figure 2.8.

Figure 2.8: Trip-distribution summary



Mode Choice

Mode choice can be defined as the intention of travellers in choosing their mode of transport for their trips. Mode choice is highly dependent on a traveller's personal intentions to choose the means of travel. Examples of modes of transport include walking, bicycling or driving any type of motorised vehicle, or choosing public transport for travelling from one zone to another zone. Ashalatha, Manju and Zacharia (2013) describe the mode-choice step as a process of arriving at a decision about a specific mode of transport under a set of circumstances. They have modelled and analysed the mode-choice behaviour of commuters in a case study of Thiruvananthapuram, in India.

Trip Assignment

The route choice, or assignment stage, is the fourth step in FSM. In this step, all the distributed traffic between the generation and distribution zones is assigned to the road network, such as highways, freeways and roads within the locality of the area intended for modelling. Saleh, Tofigh and Zahra (2014) state that finding the optimal routes to reach the destination is considered a significant challenge for Intelligent Transportation Systems. They have proposed a mechanism which includes two phases to investigate the optimal route choice.

2.3 Gravity Model

The Gravity Model, which was first introduced by McDonald and Blunden, is the most well-known **synthetic model** for estimating trip distribution (Erlander and Stewart 1990). It is widely used in transportation engineering and is based on Newton's concept of gravity (Erlander and Stewart 1990.). Equation 2.1 below depicts the Gravity Model in distributing the traffic between generation and attraction zones.

$$Tij = Pi * \frac{Aj\ Fij\ Kij}{(\sum_{j=1}^{n}(Aj\ Fij\ Kij))} \qquad (2.1)$$

where:

Tij= Number of trips from zone i to zone j

Pi= Number of trip production in zone i

Aj= Number of trip attraction in zone j

Fij= Friction or balancing Factor (represents the spatial separation between zone i and j)

Kij= Optional adjustment factor, recommended to be 1.

Equation 2.1 is considered as the basis in most of the transport engineering studies to determine the trip distribution between the zones in the area of the modelling.

Therefore, the technique used in this research to estimate trip distribution is the Gravity Model.

2.4 Deterrence Function

Finding a way to introduce the impact of distance into the Gravity Model has been a common area of research in recent years. It is evident that travellers prefer to travel to closer destinations for different trip purposes such as work, education or shopping. Various research studies have been undertaken in recent years to investigate traveller behaviour, especially in terms of specific travel purposes such as work.

Based on data sourced from the Office for National Statistics in the UK (2014), in 2011 the average distance commuted to work in London was around 11 km, while in Wales in the same year it was about 15 km. As a general guide, workers would prefer to find accommodation as close as possible to their workplace, and would be very reluctant to find a place to live that is far from it. Day, Habib and Miller (2010) undertook research to investigate the impact of trip timing and duration on the travel for commuters to work in the Greater Toronto Area (GTA). Their analysis focused on a typical three hours of the morning and afternoon peak period. The researchers also investigated the relationship between the trip-timing decision and mode choice of the commuters to work in GTA. Elhenawy, Chen and Rakha (2014) conducted research on travel time for a case study along a 37-mile freeway section on Hampton Roads Beltway in Virginia. Their analysis was based on the travel time throughout a day (between 5 am and 10 pm). They also developed a generic program algorithm to predict the travel time of future commuters.

For accurate transport modelling, and in order to incorporate the impact of distance and time on human travel behaviour, different friction factors have been introduced to the Gravity Model over the years.

The Gravity Model for trip distribution considers some balancing factors (Fij, as shown in Equation 2.2), which are known as deterrence functions. Different equations have been studied to estimate deterrence functions, such as the Gamma function, Exponential function, Power function, or a combination of both the Power and Exponential functions.

Below is a list of the various equations which have been used so far to estimate the deterrence function, as suggested by Ortúzar and Willumsen (1994):

$$Fij = a * e^{-b(cij)} \tag{2.2}$$

$$Fij = a * cij^{-b} \tag{2.3}$$

$$Fij = a * cij^{b} * e^{-(cij)} \tag{2.4}$$

In all the above equations, cij is an element which directly influences the trip distribution. This factor is known as the Generalised Cost in the literature, and it can be considered to be distance, time or the combination of time and distance (Mathew and Rao 2006).

2.5 Calibration Stage – Trip-Length Calibration

A, b and c are constant numbers which differ from one area to another and are dependent on various factors. It is to be noted that each of these equations might be able to reflect the required deterrence function for modelling, but the challenge is to try to find the most suitable constants (c and/or b and/or a, b and c) which can best calibrate the trip lengths within the modelling area based on the existing situations.

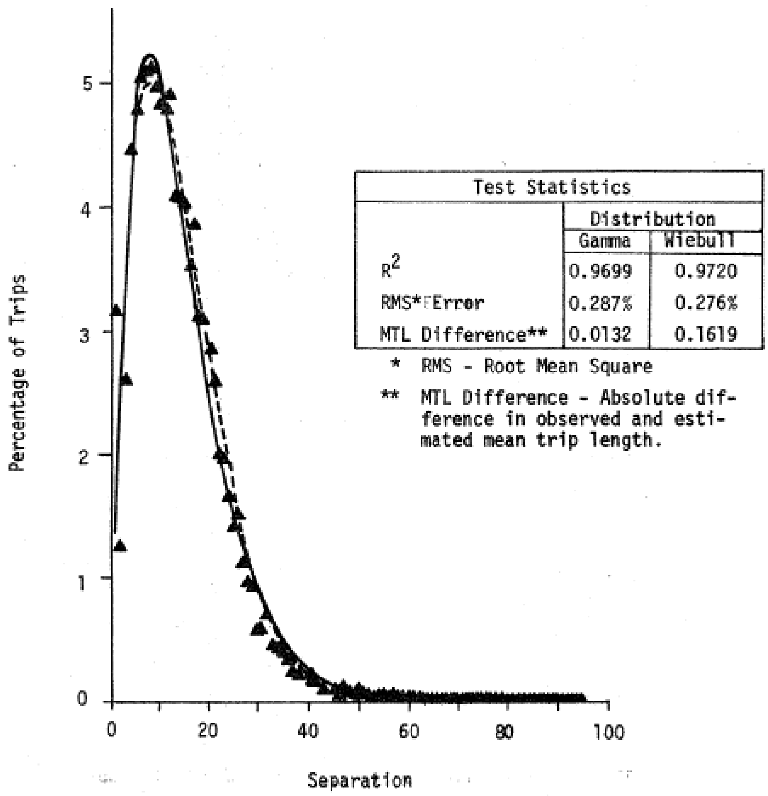
This exercise is known to be the most difficult part of the modelling task in traffic and transport engineering and is called the **calibration stage**. Shrewsbury (2012) describes the calibration of a model as a complex process and suggests that although the analytical methods have been implemented in some modelling packages, the old-fashioned trial-and-error methods are still employed for many other packages.

The calibration stage in transportation modelling aims to enhance the performance of the model to be able to best replicate the existing situations based on the on-field observations in real life. The term ‘calibration’ can be used for any aspect of the model such as volumes, time of travel, distance of travel, delays and queues. In this instance, the calibration of the friction factors is referred to as the **trip-length** calibration. Once these friction factors are calibrated based on the existing observed trip lengths (which are provided by the DoPLH as part of this research), then it can be concluded that the Gravity Model has been calibrated to incorporate the existing trip lengths. ‘Trip lengths’ is a term which relates to the actual distance of travel by commuters for different trip purposes.

Accordingly, the model trip-length calibration can be defined as the practice of trying to find the most suitable parameters (in deterrence functions) to best reflect the actual trip lengths in the modelling area. As a consequence, and when the Gravity Model is calibrated, it can then be anticipated that the trip distribution is calibrated for different trip purposes. As such, the transportation model is calibrated for trip distribution and therefore it is not expected that the model distributes the traffic in an unrealistic way. For years, modellers have always tried to calibrate their model only for time of travel and traffic volumes on links. However, calibrating the trip distribution is also necessary, as errors occurring during the trip-distribution step will be propagated to other steps of FSM and will result in an unrealistic distribution of traffic, even while the volumes on links might be matching the existing traffic volumes.

Now that the significance of trip-length calibration has been shown, we need to look at the application of similar studies in other literature. Pearson, Stover and Benson (1974) undertook a detailed study on the concept of trip-length estimation for different trip purposes in Texas, US. Their methodology was to review, test and compare the observed trip-length distributions for 18 transportation studies in Texas for home-based, non-home-based, and truck-taxi trip purposes. The researchers used Gamma and Weibull distribution models to fit the observed actual trip length against the distance of travel and compared the results. Figure 2.9 shows the outcome of the regression plots for both models. In this figure, the dotted line is the curve-fit regression undertaken by the Weibull distribution model, and the solid line is the curve-fit regression undertaken by the Gamma model. As depicted in Figure 2.9, the results for both matching techniques are reasonably close, but the Weibull distribution model resulted in a better fit.

Figure 2.9: Curve fitting for home-based work-trips length



Source: Pearson, Stover and Benson (1974)

This author acknowledges that there are not many previous studies undertaken on this concept, and this might be because the focus of model calibration is normally more on calibrating the traffic volumes and times of travel at strategic levels and less on trip-length calibration. This again confirms the significance of this study, which concentrates on details of calibrating the work-trip distribution for the Perth metropolitan area. The methodology used in this research can be applied by others so that the trip-distribution calibration will be further considered. It is noted that this research aims to investigate the work distance-deterrence functions for calibrating the trip lengths using three different methods (as per Equations 2 to 4) to try to find the best deterrence function to be proposed as the work distance-deterrence function for the Perth metropolitan area.

Other literature reviews on the concept of transportation modelling, FSM and deterrence functions are provided in detail in the following sections.

2.6 City of Lincoln Study

Lima & Associates (2006) developed a travel demand model for the City of Lincoln-Lancaster, in the UK, using TransCAD software. They chose a Gamma function to estimate the friction factors in the Gravity Model, as shown in Equation 2.5, where I is the impedance and incorporated as trip length in minutes.

$$Fij = \alpha * I^{\beta} * e^{I*\gamma} \tag{2.5}$$

After calibrating their transport model, Lima & Associates were able to establish α, β and γ for the City of Lincoln. Their studies covered different trip purposes such as home-based work, home-based shop and home-based recreational, and for all other trips which are not generated from homes they allowed for non-home-based trips.

According to their study, the friction factors in Table 2.3 have been established for the City of Lincoln.

Table 2.3:Friction factor coefficients suggested for City of Lincoln, estimated by Lima & Associates (2006)

Trip Purpose	A	B	γ
Home-based work	5000	-0.0174	-0.0425
Home-based shop	200000	0.0724	-0.1578
Home-based recreational	250000	-0.3449	-0.0658
Home-based others	15000	-0.256	-0.0886
Non-home-based	100000	-0.0056	-0.1556

Source: Lima & Associates (2006)

Another example is the research carried out by Evans and Pooler (1987). The focus of their study was to investigate the ability of different deterrence functions to replicate the observed patterns of Canadian interprovincial migrations during the period 1961–62 to 1984–85. They employed three different deterrence functions using inverse power, negative exponential and squared distance. The results of each model were analysed and it was established that for their specific modelled area, the Power model led to the best possible calibration.

2.7 Western Australia Transport Models

Across WA, which is the main focus for this research, three major transport models have already been developed and are currently in use for road planning, project evaluation and program planning (Taylor and Scrafton 2003). These models are as follows:

- Main Road Western Australia (MRWA) transport model known as ROM (Regional Operational Model)

- Department of Planning, Lands and Heritage (DoPLH) Strategic Transport Evaluation Model (STEM)
- City of Perth Model (CPM), which is a detailed model for Perth city centre.

Furthermore, a strategic transport model has recently been developed for the City of Mandurah by Transcore Pty Ltd (Bordbar and Rasouli 2012). A Gamma function was used to estimate the friction factors.

The coefficients a, b and c in a Gamma function were calibrated for the City of Mandurah and the model was found to satisfactorily replicate the existing traffic volumes on roads. This study was carried out based on three different trip purposes (work trips, education trips and other trips). The outcome of the model proved that the private car is not the first choice of transport for short-distance trips, with other modes like walking or cycling being preferred. It was also established that car trips in the City of Mandurah mostly occur within a distance of 3 to 5 km.

According to their website, the Roads and Maritime Services (New South Wales) (NSW) has also developed and maintained an EMME transportation model to undertake transport planning and future traffic forecasting (2017). According to the website, the land use data prepared and provided by the NSW Bureau of Transport Statistics are fed into the EMME model. The model consists of a major road network and a number of zones to replicate the generator and attractors of the traffic. These strategic models have also been calibrated for peak-hour situations (7 am to 9 am during the morning peak hours and 4 pm to 6 pm during the afternoon peak hours). The models for AM and PM peak hours have been reviewed to be calibrated based on the existing traffic volumes on roads.

2.8 Other Transportation Models

Abdel-Aal (2014) developed a calibrated Gravity Model for the City of Alexandria, in Egypt. He calibrated the Gravity Model for different trip purposes within the city. The formulation for trip distribution in the model was based on the general assumption that time or distance of the journey is negatively proportional to the trip destination. Abdel-Aal subdivided the modelling area into 15 zones. For the purpose of trip generation, Census data from 1996 was used. Calibration of the Gravity Model was based on the observed trip length for different trip purposes such as work, education, shopping and non-home-based trips within the City of Alexandria.

Celik (2010) undertook similar research for the City of Istanbul, Turkey. Celik used the 2006 household travel data for his research. The analysis was conducted for work, shopping and non-home-based trips. Each of the trip purposes in the study area was modelled via Exponential and inverse Power function and the respective constant coefficients were estimated for each trip purpose.

Thomas and Tutert (2013) undertook research on trip-distribution function for commuters in The Netherlands. They used the travel survey data from 1995 and 2004-2008 to evaluate the trip-distribution function for their study area, and conducted comparison analysis to investigate the people's travel behaviour for the two periods.

Qi and Ishak (2014) had analysed the travel behaviour over a 68 km corridor of Interstate 4 in Orlando, Florida. In their publication, they introduced a stochastic approach for short-term travel projection and freeway traffic pattern.

Weifeng, Zhengyu and Gaohua (2013) investigated the travel-time distribution pattern for four routes of expressways within Shanghai, China. They chose a representative weekday for working day and a typical weekend for their analysis on travel time distribution in their case studies. The outcome of their research proved the best-fitting match for the time of travel distribution in the selected expressways.

A comprehensive review of a number of different pre-established, short-term traffic forecasting models around the world can be found in a journal article by Vlahogianni, Karlaftis and Golias (2014). The researchers raised 10 challenges for short-term traffic forecasting and reviewed the already established model against these challenges.

In 2001, the University of Connecticut, in the US, established a traffic model for the entire university and the surrounding road network using the model software (2001). For the purpose of calibrating the model, the university had undertaken a 24-hour, midweek automatic traffic count for the whole university and the surrounding road network during October and November 1999 when classes were in session. After the establishment and calibration of the model, they used it to forecast the 2004 traffic projections for the university based on the background traffic, the future growth of the surrounding road traffic volumes, and the future growth of the university (University of Connecticut 2001).

de Grange, Fernández and de Cea (2010) undertook detailed research on trip distribution using the Gravity Model. The trip information they used to estimate the constant coefficients consisted of bus trip data which was collected from a large survey of Santiago bus users. Their methodology was to employ three different levels of area subdivision corresponding to three different scales, as detailed below:

- area subdivision level (1) consisting of 577 zones
- area subdivision level (2) consisting of 36 districts
- area subdivision level (3) consisting of 7 sectors.

For each of the three subdivisions the researchers were able to find the constant parameters, and furthermore conducted various statistical analyses including R^2Correlation between observed and modelled trips, LogL (Log-likelihood) and the standard Root Mean Square Error (RMSE) to investigate the reasonableness and accuracy of their model in relation to the existing data.

Ono, Chin and Lee (1987) developed a transport model for the Hiroshima urban area using EMME 2 software. The trip distribution in their study was based on the Gravity Model and the calibration was based on the targeted existing traffic volumes on roads. As part of their study, the researchers conducted R^2Correlation and RMSE assessments for the traffic volumes extracted from the model versus the observed traffic volumes. In their conclusion, the researchers made mention of the benefits of using the EMME model in transportation modelling.

Nijhout, Wood and Moodley (2001) developed a strategic transport model for the Durban metropolitan area, in South Africa. Their focus was to establish the public transportation within the model and test the accuracy of the transit lines. Accordingly, the researchers gave further consideration to the third step in FSM – Mode Choice. A comprehensive study on the percentages of different transportation modes was conducted in their research. In their conclusion, they provide the benefits of EMME software in modelling public transportation demands. However, they acknowledge the limitation of modelling for other non-private vehicles, such as taxis.

In 2009, and to address the need for a transportation model requested by Wiltshire Council, UK, Atkins Limited developed different models for the Salisbury area (2009). As a result of the review of the report prepared for this exercise, it was understood that three different models were developed for the area, of which the public transport model was developed using EMME 3 software. As such, a public transport network with transit lines for rail and buses was developed. The assessments of 'park'n'ride' application were also included in the model. This exercise led to a model that became an asset for the council that was then used for sub-area modelling and analysis.

Wang et al. (2017) state the importance of the existence of a calibrated model for urban redevelopment studies in metropolitan areas. The research carried out included assessments of the traffic impacts as a result of redevelopments, in a case study of the State of Maryland, US. The researchers had used the pre-established transportation model for the state to conduct various traffic impact assessments with respect to different redevelopment scenarios. As part of the research process, they also studied the application of FSM for the Transit Oriented Demand scenario, which was previously introduced to the statewide model. The outcome of the study was a post-trip distribution assessment based on different redevelopment scenarios.

Tehran, the capital city of Iran, has always had significant traffic issues, and as such many remedial measures have been discussed to resolve traffic congestion in the city. One of these measures is the application of auxiliary bus transit routes. The Bus Rapid Transit (BRT) system is now widely implemented in Tehran. As part of the assessments undertaken, Zakeri Sohi (2007) undertook EMME transportation modelling for the BRT system in Tehran and compared the daily traffic volume changes as a result of the availability of the BRT system.

2.9 Transport Planners' Opinion

te Brömmelstroet et al. (2017) have undertaken an interesting survey (in the form of a questionnaire). Their survey was to establish the respondents' feedback regarding the use of transportation models for the purpose of transportation planning and decision-making processes. The groups for whom the survey was conducted covered both transport planners and stakeholders. The researchers developed an online survey for 229 respondents primarily working in Germany, The Netherlands and Denmark. The result of their survey recommends that most of the transport planners do understand the significance of transportation modelling; however, they acknowledge the shortcomings of the models, their restrictions and uncertainties. The reason for mentioning this work here is to demonstrate the importance of transportation modelling for substantial decision-making processes. It could be concluded from te Brömmelstroet et al's research that transportation modelling is widely supported by planners around the world and, in particular those in European countries discussed in his paper.

2.10 Other Deterrence Functions in Use

Although the most well-known deterrence functions in use are those depicted in Equations 2 to 4, several different, and less common, deterrence functions have now been incorporated into various software packages, which prove the importance of these functions in providing a robust and reliable distribution model. In order to keep the area of research open for further review, some of the functions are briefly introduced, and examples presented, in this document. The Box-Cox and Box-Tuckey functions are mainly used in the VISUM and VISSIM software packages (PTV Planung Transport Verkehr 2001).

Chalumuri et al. (2013) have undertaken research to investigate delay and fuel loss during the time that vehicles are stationary at signalised intersections, for a case study in Ahmedabad, in India. The researchers used VISSIM Microsimulation software to simulate the traffic movement. For the calibration, a 16-hour traffic count was conducted at four signalised intersections of a busy road within the city of Ahmedabad. The researchers' analysis, based on the observed count, shows that simulation errors resulting from the VISSIM software were reasonably low.

Siddharth and Ramadurai (2013) undertook traffic modelling via VISSIM software. Their case study included an area near Tidal Park intersection in Chennai, India. After calibrating the model, they conducted different sensitivity analyses to investigate the impact of different parameters which affect driving behaviour.

Long-normal and top long-normal are used in the omniTRANS software package and the Eva Model, which uses impedance functions that show significantly higher elasticity (Lohse 2004).

It is believed that the examples provided in this section sufficiently show the importance of transportation modelling around the world and prove the indispensability of such studies and exercises. The author has also aimed to demonstrate the importance of the trip-distribution step and its calibration practice by providing a number of case studies in past research.

Considering a rapid growth in population and the expansion of the Perth metropolitan area, travel behaviour research is significantly required for transportation planning and future infrastructure provisions.

2.11 Summary

A comprehensive review of the available literature was presented in this chapter. The focus of the literature review was to establish the significance of trip distribution, trip-length calibration, transportation modelling and the application of deterrence functions in the Gravity Model for trip distribution.

The review of the available literature clarifies the importance of this research and confirms the importance of trip-distribution techniques in traffic and transportation areas.

Undertaking such strategic studies is considered indispensable for different cities and they are common around the world. The application of strategic modelling becomes even more important when considering the rapid growth of WA, especially Perth City.

A critical review of the current literature was undertaken by the author, Dr. Amin Chegenizadeh and Professor Hamid Nikraz during the course of this research. Entitled "A Critical Review of Current Transport Models", it is attached as Appendix A1.

Table 2.4 shows a summary of the literature presented in this chapter.

Table 2.4: Summary of the literature review

Researcher (Year)	Scope and method	Outcome of the research
Wu and Liu (2014)	Analysing the accuracy of two methods for the traffic data collection and comparing the reliability of them	The use of the high-resolution event data would lead to a better and more reliable traffic data collection compared to the conventional fixed-point sensors
Taplin, Taylor and Biermann (2014)	Conducting a comprehensive review of different levels of transportation modelling	Comprehensive review and detailed studies undertaken by Curtin University, The University of Western Australia and Edith Cowan University in conjunction with DoPLH, MRWA and Western Australian Local Government Association contained in the report, which demonstrates different aspects of transportation modellings, their requirements and applications
Bliemer et al. (2013)	Developing a new traffic assignment which brings dynamic behaviour into strategic modelling (quasi-dynamic assignment)	Detailed review of the application of quasi-dynamic assignment on four different case studies (two in The Netherlands and two in Australia)
Madi (2016)	Developing a Microsimulation model using Aimsun software for a section of Outley Road, Leeds, UK	An Aimsun Microsimulation model was developed for the AM/Off peak period as part of the study, and the dynamic features were reviewed and analysed for different options
Bwambale, Choudhury and Hess (2017)	Proposing a hybrid model for estimating the trip generation of the study area	A detailed discussion on various trip generation methods has been provided in this publication, and a new way of trip generation estimation using a hybrid model is also provided
Mousavi, Bunker and Lee (2012)	Conducting comprehensive research on the available Australia and New Zealand trip generation policies and guidelines	There is currently a great need for data reflecting trip generation for different land uses in Australia. The paper also recommends the government in different states to conduct different surveys and collect the trip generation information for different land uses and trip-makers

Ashlatha, Manju and Zacharia (2013)	Analysis of the preferred mode choice of the commuters for a case study in India	The analysis shows that an increase in time and cost per distance pushes commuters to use cars and two-wheelers instead of public transport
Rasouli (2014)	Using the application of Neural Network for distributing the traffic	The analysis presented in this research shows the accuracy of using Neural Network for trip distribution practices.
Wang et al. (2013)	Sharing the disadvantages of the lack of transport models for urban areas in China.	The discussion recommends a framework to develop a multimodal transport model using the application of FSM.
Saleh, Tofigh and Zahra (2014)	Proposing a mechanism for vehicle route choices	Researchers were able to propose a step-by-step algorithm for the route choice and traffic assignment
Day, Habib and Miller (2010)	Undertaking analysis of travel trends for travellers to work in Greater Toronto Area (GTA)	Developing a joint analysis for trip timing and mode choice for a typical three hours in morning and afternoon peak period of GTA
Elhenawy, Chen and Rakha (2014)	Undertaking analysis on travel time of the commuters for a section of Hampton Road Beltway in Virginia	Proposing a generic programming algorithm to estimate the travel time of commuters
Pearson, Stover and Benson (1974)	Undertaking analysis on trip-length estimation for Texas, US	Review the actual trip-length data based on 18 transportation studies and curve-fitting analyses based on Weibull and Gamma models
Lima & Associates (2006)	Developing a travel demand model for the City of Lincoln-Lancaster, in the UK, using TransCAD software	Developing a travel model for the City of Lincoln and calibrating the deterrence function
Evans and Pooler (1987)	Finding the best deterrence function to replicate the pattern of Canadian interprovincial migrations during the period 1961–62 to 1984–85	For their modelled area, it was shown that Power model yielded the best calibration

Regional Operational Model (late 1970s)	Developing a strategic model for the Perth metropolitan area using CUBE software	A strategic model for the entire Perth metropolitan area
Transcore Pty Ltd (2012)	Developing a strategic model for the City of Mandurah using EMME software	A strategic model for the City of Mandurah and calibrating the deterrence function based on Perth and Regional Travel Survey data
Roads and Maritime Services (NSW) (2017)	Developing an EMME model for three hours AM and three hours PM, peak hours	The calibrated models for the AM and PM peak hours are used for future traffic forecasting and future planning decisions
Abdel-Aal (2014)	Developing a transport model for the City of Alexandria, Egypt	A calibrated model for different trip purposes such as work, education, shopping and non-home-based trips within the City of Alexandria
Celik (2010)	Developing a transport model for the City of Istanbul, Turkey	A calibrated distance deterrence function and respective constant coefficients for Istanbul
Thomas and Tutert (2013)	Developing a distribution function for commuters in The Netherlands	Conducting comparison analysis to investigate the travel behaviour of commuters for two periods of time
Qi and Ishak (2014)	Undertaking a detailed analysis of existing travel pattern on a corridor of Interstate 4 Orlando, Florida	Proposing a stochastic approach for short-term traffic projection called a Hidden Markov Model
Weifeng, Zhengyu and Gaohua (2013)	Analysing the travel time distribution for four routes of expressways within Shanghai, China	Finding the best-fitting match for distribution of the travel time for a typical weekday and a typical weekend
Vlahogianni, Karlaftis and Golias (2014)	Undertaking a comprehensive review on the pre-established, short-term traffic prediction models	The pre-established models were analysed based on 10 challenges and a set of recommendations were provided for the betterment of the traffic-forecast modelling
University of Connecticut (2001)	Developing a transport model for the entire university and the surrounding road network using the model	A calibrated model which was then used to forecast the future traffic (2004) based on the land-use growth and background-traffic growth

de Grange, Fernández and de Cea (2010)	Employing three different subdivision levels for Santiago area	Calibrated Gravity Model for the bus users within the modelling area and conducting multiple statistical analysis to investigate the accuracy of their model
Ono, Chin and Lee (1987)	Developing an EMME 2 transportation model for the Hiroshima urban area	A calibrated EMME model for the Hiroshima urban area and advice on the benefits of using EMME software for transportation modelling
Nijhout, Wood and Moodley (2001)	Developing a transportation model for the Durban metropolitan area to replicate the public transportation demand	A calibrated public transport model was established, in which it was used for undertaking different future public transport demand analysis
Atkins Limited (2009)	Developing an EMME 3 software transportation model for the Salisbury area to replicate the public transportation demand	A calibrated public transport model was established in which it was used for future demand analysis and sub-area modelling activities
Wang et al. (2017)	Using the pre-established transportation model developed for the State of Maryland, US, to conduct different assessments of redevelopment scenarios in the metropolitan area	The study confirmed the importance of the existence of a transportation model to enable the researchers to assess the impact of redevelopments
Zakeri Sohi (2007)	Establishing an EMME model to replicate the advantages of the BRT system for Tehran	The EMME model could demonstrate the changes in the daily and hourly traffic volumes as a result of the BRT implementation
te Brömmelstroet et al. (2017)	Undertaking an online survey of 229 transport planners and stakeholders to establish their feedback regarding the importance of transportation modelling for substantial decision-making processes	The importance of transportation modelling was acknowledged and it was established that the planning firm understands the shortcomings of the models; however, they recognise the need for such exercises to be undertaken for decision-making processes

Chalumuri et al. (2013)	Developing a Microsimulation model using VISSIM software for a typical road within the City of Ahmedabad, India	Calibrating the Microsimulation model based on the observed 16-hour counts and conducting analysis on the reliability of the VISSIM model
Siddharth and Ramadurai (2013)	Developing a Microsimulation model using VISSIM software for a typical corridor within the City of Chennai, India	Calibrating the model and undertaking sensitivity analysis for people's travel behaviour

3 BASIC CONCEPTS

3.1 Four-Step Modelling

Four-step travel modelling is a traditional way of travel forecasting which works in four steps.

Step one is the trip generation, which estimates the total number of trips from the trip production zones onto the attraction zones. Step two is referred to as the trip distribution which, in a simple way, deals with distributing the generated trips from the origin zones onto the destination zones. Step three, which is referred to as mode choice, deals with the question of what mode of transport will be chosen for the purpose of travelling from the production zones onto the destination zones, and step four, which is referred to as the assignment step, is to determine the route which will be taken for any trips.

3.2 Trip Distribution

Trip distribution is the second step of Four-Step Modelling (FSM). The main concept of trip distribution is to calculate the number of the trips between each two pair of zones. Trip distribution is a function of time and distance and is dependent on how many trips are anticipated to occur between the two zones.

Trip distribution can be established through a matrix which relates the number of generated trips between each traffic production zone to the traffic attractor zones. This matrix is called an Origin Destination (OD) matrix. Assessment of the trip distribution is a difficult and challenging task.

In order to have a robust transport model it is important to calibrate the trip distribution as accurately as possible. Otherwise, the model may distribute the traffic in an unrealistic way. In other words, it is important to calibrate the model in such way that it distributes the traffic as it occurs in real life. Therefore, there are two OD matrices which need to be considered to evaluate the efficiency of the trip distribution method:

- the observed OD matrix which points to the actual number of trips measured within the modelling area (Base Year OD matrix)
- the OD matrix which is produced by the software.

Comparing the two OD matrices will result in a better understanding of whether the model is behaving as it should in the real world. The distributed traffic on the roads can be compared with the observed traffic volumes in existence on these roads. This practice is called the calibration of the traffic volumes for the Base Year. Base Year is so called as the year in which the model has been calibrated for. In this research study, the Base Year has been selected to be for the year 2011. The reason for choosing 2011 is due to the availability of the latest household survey data at the time of preparing the transportation model for year 2011.

Accordingly, the EMME transport model used in this research has been calibrated to replicate the actual traffic volumes reported for the major roads within the Perth metropolitan area.

3.3 The Gravity Distribution Model

The Gravity Model in distributing the traffic is comparable with Newton's gravity theory. This method works on the basis that the total trips between the generator zones and attraction zones for different trip purposes are proportionally related to the number of trips between them, and has a reverse relation with the frictions available between them.

The frictions discussed in this method can be different in nature, such as the distance of travel, time of travel, cost of travel, as examples, which impedes commuters to choose their destinations. As a rule of thumb, people will prefer not to choose their destinations very far from where they live or work if alternatives for the trip purpose are available.

The calibration of a Gravity Model works with calibrating these friction factors. Before using a Gravity Model for future traffic predictions, the model needs to be calibrated for the traffic volumes of the Base Year scenario.

3.4 Generalised Cost

To replicate the friction factors, which may impede the traveller to choose their destinations, the concept of generalised cost has been introduced to the Gravity Model.

The impediments which can stop someone from choosing their destination can be distance, time, delays, cost of fuel and parking charges, as examples.

Accordingly, the generalised cost is considered as the separation between the origin zones and the destination zones.

3.5 Deterrence Function

The Gravity Model is considered to be a robust mean for distributing traffic on the road network because the Gravity Model considers people's actual travel behaviour when distributing the traffic. This concept of taking people's travel behaviour into account when distributing traffic is introduced to the Gravity Model via the concept of generalised cost, and the generalised cost itself works with a number of friction factors which are called deterrence functions.

Deterrence functions can be studied for different trip purposes such as work trips. It is noted that deterrence functions for an area of modelling are not unique and are supplemented with a number of constant coefficients.

These coefficients can be derived from different methods (which will be further discussed in Chapter 5). However, the challenge is to calibrate these coefficients in such a way that the Base Year model is reflective of the existing trip-distribution pattern.

The correct calibration of the deterrence function leads to a calibrated Gravity Model and, moreover, a more reliable Base Year model which can then be used for future scenarios.

3.6 Trip Length

The trip length is defined as the length of a trip measured in time or distance. Distance trip length is known as the distance of travel (for example, measured in units of kilometres) from origin zones into the attraction zones. For instance, the trip length for a particular home-based work trip is the distance from the particular production zone (home) to the attraction zone (work places). Finding a way to accurately estimate the trip length is a difficult task and most transport modellers normally miss this step in the calibration stage. Traditionally, transport modellers always try to calibrate the traffic volumes to ensure accuracy of the model performance. This approach for calibration, however, only works with traffic volume matching on links and does not allow for calibration of the actual trip-length estimation. Put simply, on a *link A,* the modelled traffic volume might be estimated to be close to the actual traffic volumes for the Base Year, but the question is whether the trip distribution resulting in traffic-volume estimation for that link reflects the actual trips distributed on that link. The proposed methodology in this research to calibrate the trip length is to analyse the actual OD data provided by Australian government agencies to try to find a theoretical approach to estimate the trip length and compare it with the actual data.

The actual trip lengths are normally obtained from surveys conducted by governments in the form of questionnaires or online forms. In these surveys, people are asked about their daily destinations for different trip purposes, such as work trips. To illustrate the point, anyone who lives in the northern suburbs is asked to state their work-trip destination and the results are compiled on a suburb-to-suburb basis. This information is then translated into a table which demonstrates the total number of trips from each suburb (traffic zones in our study) into other suburbs (traffic zones in our study).

For this research, the trip-length information was provided for work trips by the DoPLH in a tabulated format which incorporated the total number of trips for the Base Year (Year 2011) between different pairs of suburbs at Statistical Level 2 (SA2). The definition and application of SA2 will be explained in greater detail in Chapter 4.

The next challenge to estimate the actual distance of the trip length is to estimate the distance of travel between each of the two zones. For this research, the accurate distances between each pair of zones were obtained from the EMME transportation model which was developed as part of this research. Finally, the actual trip numbers and the actual distances were available so that a graph could be plotted to show the actual distance trip lengths.

To estimate the theoretical trip length, this graph was then analysed with respect to different deterrence functions using three different models: Gamma, Exponential and Power models, as explained in Chapter 2. A non-linear trend line analysis was conducted in SPSS software to estimate the theoretical trip lengths for Gamma, Exponential and Power functions.

Once the analysis was completed, two different trip lengths were available, as follows:

1. Actual trip lengths obtained from the actual travel survey data for the Perth metropolitan area.

2. Theoretical or estimated trip length based on the different deterrence functions established for the Perth metropolitan area.

The outcomes of points 1 and 2 were then plotted against each other to estimate the best-fitting match in consideration of the calculated R^2 of the trend lines. It is expected that the greater the estimated R^2, the better the calibration of the trip length results.

3.7 Self-Sufficiency

The term 'self-sufficiency', in general, is defined as someone or something that can self-sustain oneself without using much outside resources. From a transportation perspective, self-sufficiency can be defined as distributing the traffic in consideration of available resources, limitations and distances between the production and attraction zones for different trip purposes. It is logical to expect that people would choose their accommodation closer to where they work, select their children's school closer to where they live, or perhaps choose their shopping trips as close as possible to where they live. Therefore, it is claimed that if the transportation model is calibrated for the actual distance of the trip length, this factor should be satisfactory for the trip distribution. As an example, in a modelling area where an intensive residential area is located in a traffic zone, it is anticipated that, primarily, the shopping trips are mainly concentrated towards the closest shopping centre available to the residents without the model distributing the shopping trips too far away. This is a factor which should be cross-checked to establish the efficiency of the transportation model in terms of trip distribution. A calibrated trip length is anticipated to increase the self-sufficiency by distributing the trips in a logical manner and based upon actual travel patterns.

This research will review the home-based work-trip length and proposes a distance-deterrence function. As part of the analysis which will be discussed in this thesis, self-sufficiency of the work trips in the Perth metropolitan area will also be discussed.

3.8 Summary

This chapter provided a brief explanation of the concepts of more focused subjects within this thesis. It aimed to explain the concepts in a simple and brief way so that they can be understood by the reader. More details of these concepts and their applications to this thesis will be discussed in further scientific detail throughout this document.

4 MODEL INPUTS

The land-use information used to develop the transportation model as the model inputs is from the latest available data provided by different governmental agencies as part of this research. A brief overview of the model input information is as follows:

- household data for the year 2011 (Base Year)
- schools, universities and TAFE (Technical and Further Education Organisation)
- employment data
- commercial Net Lettable Area (NLA) – including businesses and offices
- industrial area (NLA)
- showroom and warehouses (NLA)
- retail areas (NLA).

4.1 Household Data

The Australian Bureau of Statistics (ABS) is a governmental agency which provides household statistics of Australia. The ABS conducts Australia-wide household surveys on a regular basis. The main purpose of these surveys is to establish the country's latest population, geographic data, economic data, and the like. These surveys contain reasonably high-level detail and are available online, upon registration with the ABS website.

For this research, the latest available data for the year 2011 had been requested from the ABS and through formal correspondence.

ABS data follows a hierarchical structure which comprises seven levels of geographical Mesh Blocks (MB). MB is referred to as a statistical area (SA) on the ABS website: put simply, it is considered a zoning system.

Each of these SAs is aggregated to its refined and smaller SA, with SA1 being the smallest zoning system.

4.1.1 SA1 Definition

SA1 is the smallest MB and covers areas with a population between 200 and 800, with an average of 400. There are 57,523 SA1 regions which cover the whole of Australia (ABS 2016, SA1). SA1 is considered a highly detailed level for establishing the model for the entire Perth metropolitan area and Peel region, and has therefore not been used for this research

4.1.2 SA2 Definition

SA2 is the medium-sized MB, which is built from aggregating SA1-designated MB to build a population range from 3,000 to 25,000, with a medium population level of 10,000. According to the ABS website, there are 2,310 SA2 regions across Australia (2016, SA2). SA2 also covers the significant urban areas and tourism regions across Australia. In September 2015, the extracts of SA2 household data for the entire country were requested of the ABS and converted to a Microsoft Excel spreadsheet. SA2 level information for Perth and the Peel region were then extracted for further assessment.

The results of the SA2 household survey 2011 will be discussed in further detail in section 4.2.

4.1.3 SA3 Definition

SA3 is the regional level MB, which is built from aggregating SA2-designated MB to build a population range from 30,000 to 130,000, with a medium population level of 80,000. According to the ABS website, there are 358 SA3 regions across Australia. SA3 is designed to cater for regional areas and cities with a population of more than 20,000 that are accessed via major means of transport (2016, SA3).

4.1.4 SA4 Definition

SA4 is considered the largest sub-state level MB, which is built from aggregating SA3-designated MB to build a population range from 100,000 to 300,000 outside metropolitan areas and 300,000 to 500,000 in metropolitan areas. According to the ABS website, there are 107 SA4 regions across Australia (2016, SA4).

4.1.5 Australia (AUS) and State / Territory (S/T)

Australia is considered the largest MB in the ABS hierarchical structure and includes six states and two mainland territories, plus four offshore territories (2016, Australia and State/Territory):

- New South Wales
- Victoria
- Queensland
- South Australia
- Western Australia
- Tasmania
- Northern Territory
- Australian Capital Territory
- Jervis Bay Territory
- Territory of Christmas Island
- Territory of the Cocos (Keeling) Islands
- Territory of Norfolk Island.

4.2 Household Data for SA2

The basis for establishing the model is for SA2 level data to represent a reasonable level of detail for the transportation modelling.

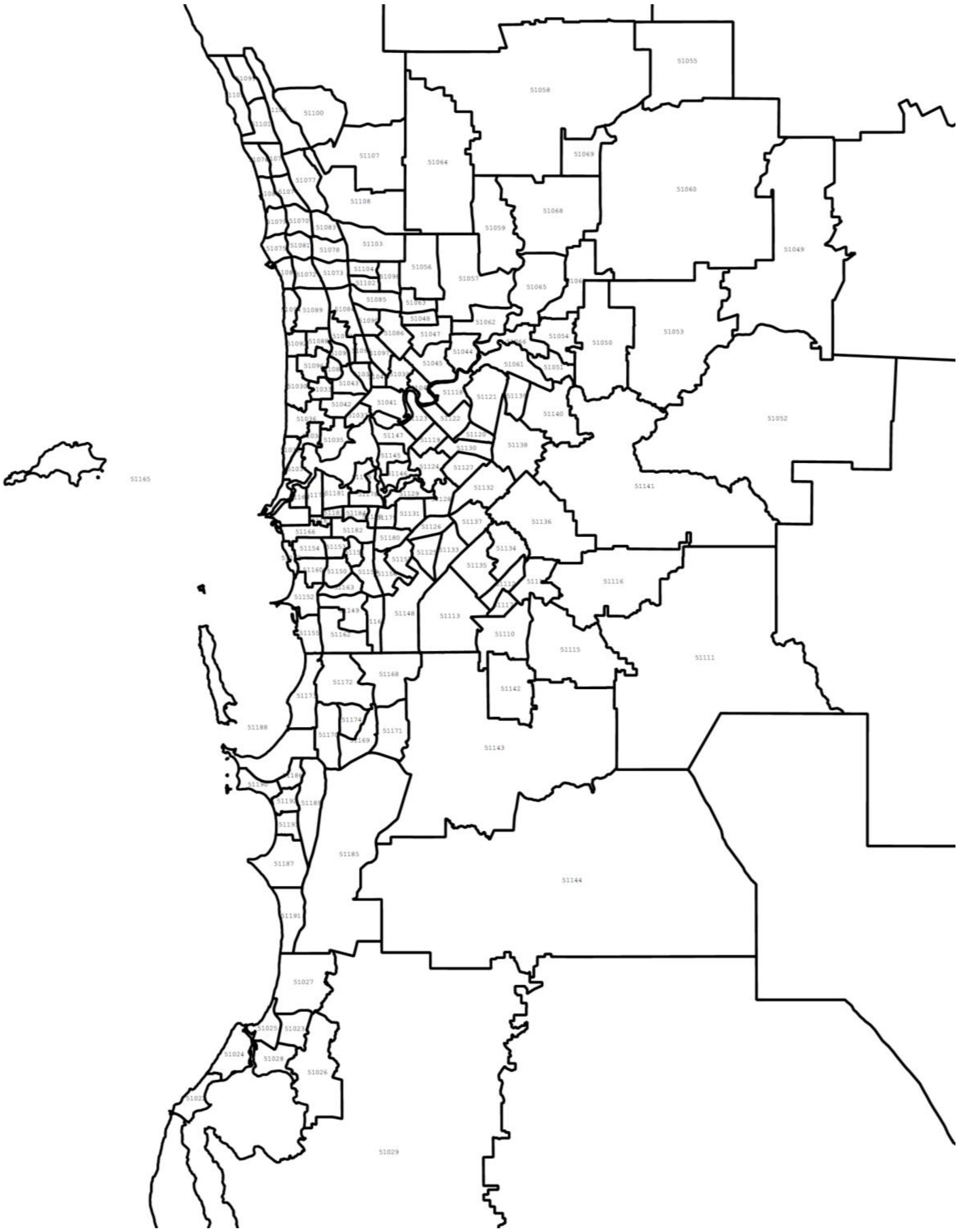
Accordingly, the data for the entire Perth metropolitan area and Peel region was extracted and assessed for the population reported by the ABS (number of male and female). Furthermore, through liaison with the ABS, the number of people in each SA2 zone was converted to an estimation of the number of dwellings.

For consistency in analysis, the same zoning system of SA2 was used for the number of employment and commercial, industrial, retail, showroom and student data.

The SA2 household information is supplemented with a shapefile to demonstrate the boundaries of each SA2. Shapefiles are available on the ABS website for free download. The SA2 zones subject to analysis in this research are from zone number 51021 to 51193 (inclusive).

A shapefile was used to establish the boundaries for each modelling zone. Accordingly, the entire Perth metropolitan area and Peel region was divided into a total of 173 (51193-51021+1) zones as shown in Figure 4.1.

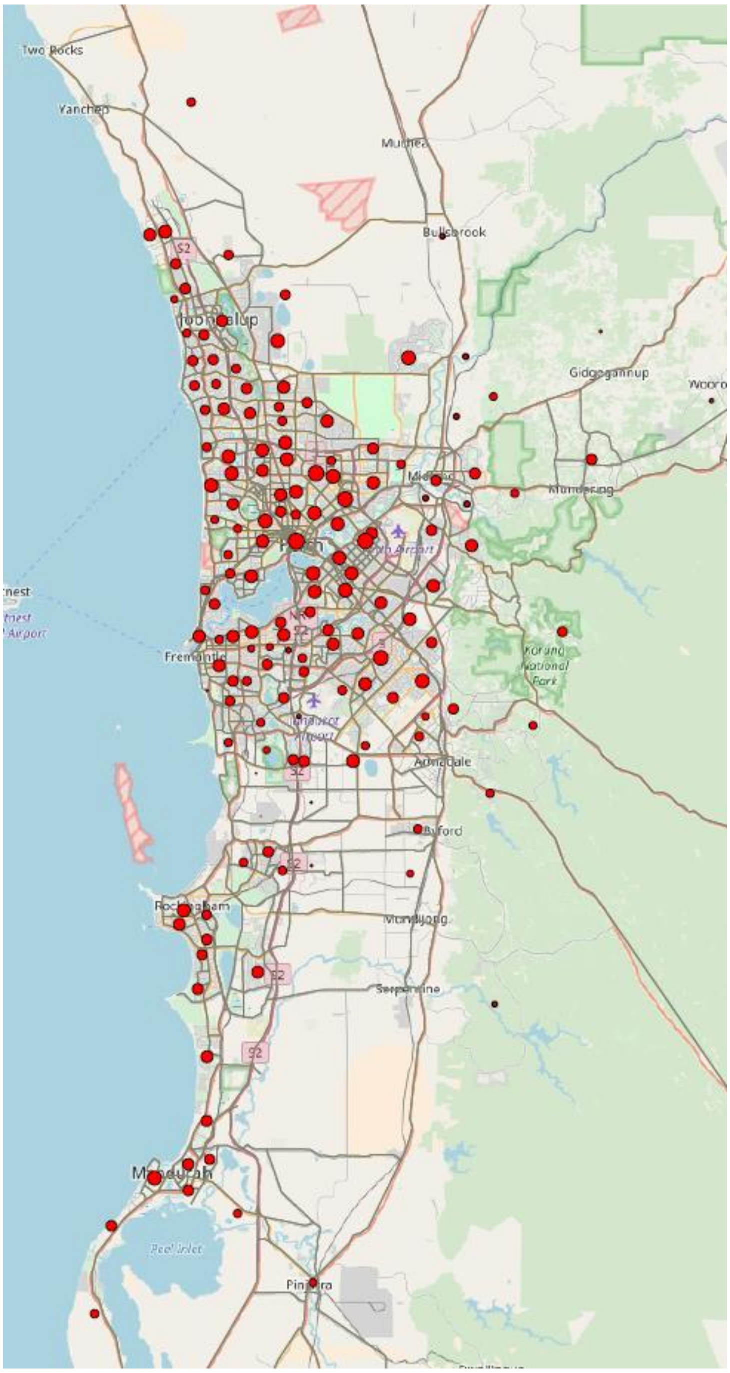
Figure 4.1: Zoning system at SA2 level



The total number of males, females and total number of people (male + female) and the estimated number of dwellings were assigned to each zone and are detailed in Table 4.1 towards the end of this chapter.

In Figure 4.2, density of the residential dwellings within each SA2 zone is proportional to the size of the red circles.

Figure 4.2: Residential zones



4.3 School, University and TAFE Data

The information related to the number of students in different SA2 zones has been provided by the ABS. The student data used for the modelling does not allow for sexual difference. Details of the student numbers for each zone are included in Table 4.2 towards the end of this chapter.

4.4 Employment Data

The employment data has been provided by the ABS for each zone within the SA2 level. The employment data includes the number of employees for each zone and does not allow for sexual difference. Details of the employment data are included in Table 4.2 towards the end of this chapter.

4.5 Commercial Information NLA

The input for the established transport model is related to the NLA of commercial, business and office premises for each zone within SA2. This information has been obtained from the Commercial Land Use Survey data, which is available online from the Department of Planning, Lands and Heritage (DoPLH) website (2017). Copies of the Commercial Land Use Survey maps are attached in Appendix B.

DoPLH's commercial information was provided at the local government level and not the SA2 level. The challenge was to try to translate this data into the SA2 level. Therefore, and through liaison with the DoPLH, a shapefile including details of the local government zone boundaries was obtained.

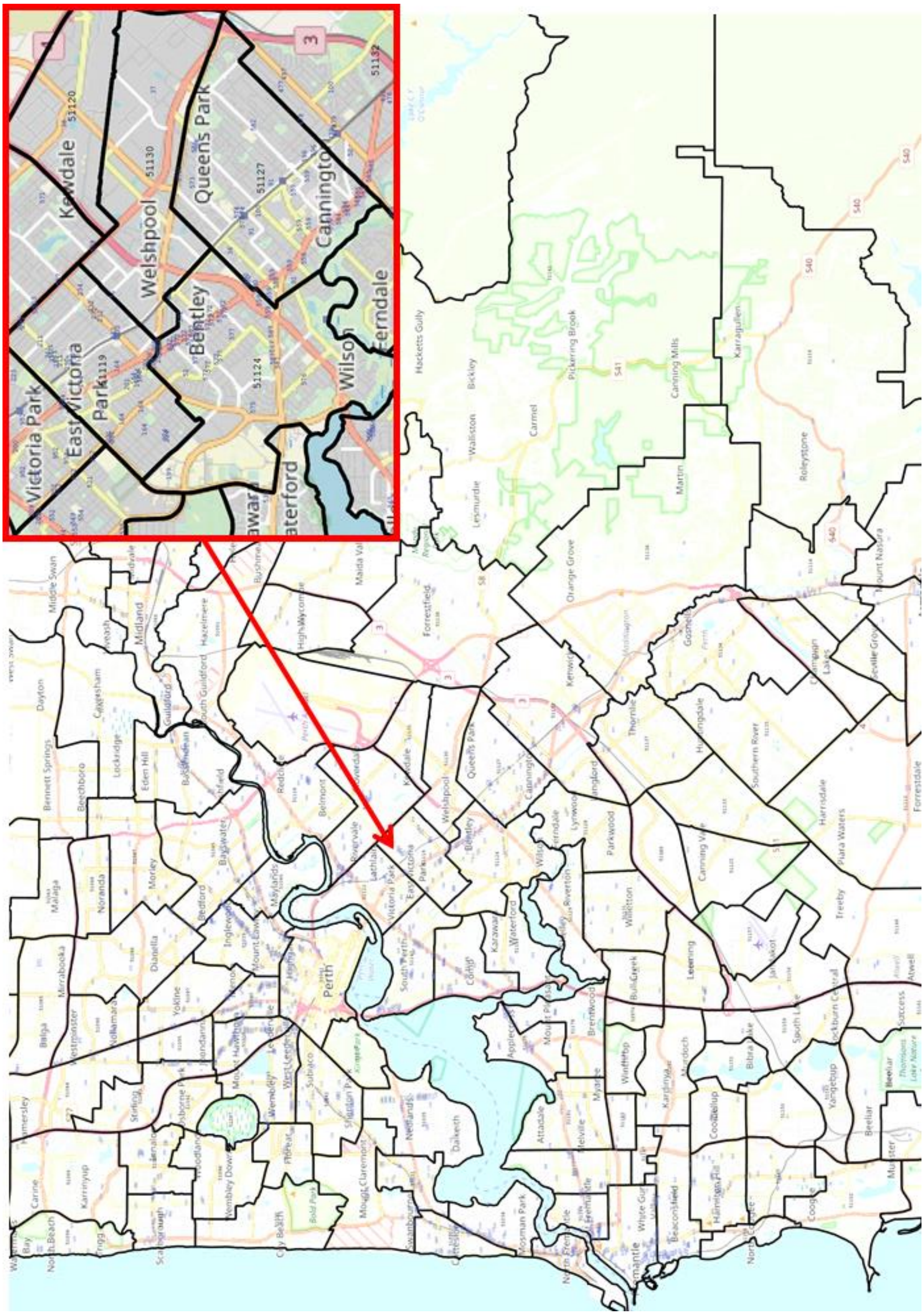
The commercial land use data is presented in the following format:

- within the boundary of each local government area there are blue dots (which are numbered) and these show the approximate location of the commercial activities within each local government area (see Figure 4.3)
- each of the commercial activities shown as a blue numbered dot in Figure 4.3 has its own floor space area. The floor area for each commercial activity was presented in pdf format, downloaded from the DoPLH's website. The floor area provided for commercial land uses was for NLAs (refer Appendix B for details).

In Figure 4.3, a section of the figure is zoomed-in, captured and located at the top right-hand corner of the figure. The magnified area selected shows suburbs around Curtin University.

Note: Figure 4.3 only shows a selected section of the entire Perth metropolitan area which is the subject of the modelling in this research; however, this exercise was undertaken for the entire metropolitan area shown in Figure 4.1.

Figure 4.3: Commercial areas (Blue dots show the location of each commercial zone)



Accordingly, the location of the commercial areas within their respective local government was available, and the information of each commercial activity was also available in pdf format. The pdf information (refer to Appendix B) was manually converted into a Microsoft Excel spreadsheet and the shapefile was read via MapInfo software.

To relate the commercial land uses from the Commercial Land Use Survey with the SA2 zoning system, the shapefile for the Commercial Land Use Survey data was superimposed onto the SA2 shapefile via MapInfo software, and the location of each commercial land use was distinguished within the SA2 zones.

To simplify the process, the summation of all the commercial NLAs was assigned to each one zone at the SA2 level to account for the total commercial area for that zone.

Accordingly, the details of the NLAs for each commercial land use within SA2 zones are attached in Table 4.2.

4.6 Industrial Area (NLA)

The input for the established transport model is related to the NLA of the industrial areas for each zone within SA2. This information has been obtained from the Commercial Land Use Survey data (as already discussed).

A similar exercise to that conducted for the commercial areas was undertaken to establish the industrial areas within the SA2 zoning level.

Accordingly, the details of the NLAs for each industrial land use within SA2 zones are included in Table 4.2 towards the end of this chapter**.**

4.7 Showroom and Warehouses (NLA)

The input for the established transport model is related to the NLA of the showroom and warehouse for each zone within SA2. This information has been obtained from the Commercial Land Use Survey data (as discussed previously). A similar exercise to that conducted for the commercial and industrial areas was also undertaken to establish the showroom and warehouse areas within the SA2 zoning level.

Accordingly, the details of the NLAs for each showroom and warehouse areas within SA2 zones are included in Table 4.2 towards the end of this chapter.

4.8 Retail Area (NLA)

The input for the established transport model is related to the NLA of the retail areas for each zone within SA2. This information has been obtained from the Commercial Land Use Survey data. A similar exercise to that undertaken for the commercial, industrial and showroom areas was also undertaken to establish the retail areas within the SA2 level.

Accordingly, the details of the NLAs for each retail land use within the SA2 zoning level are included in Table 4.2. Once all the model inputs were analysed, they were inserted into a consolidated Microsoft Excel spreadsheet that demonstrates the number of dwellings, number of students, number of employments and NLAs for commercial, industrial, showroom and retail floor spaces for each zone within SA2.

The model input was then prepared for use in the trip-generation step, which will be discussed in further detail in Chapter 5.

Table 4.1: Household information for SA2 level (Year 2011) – used for transport model

SA2_5DIG11	SA2_NAME 2011	Total_M_2011	Total_F_2011	Total_P_2011	Dwelling-2011
51021	Dawesville – Bouvard	2906	2909	5815	2887
51022	Falcon – Wannanup	3935	3877	7812	4495
51023	Greenfields	5061	5339	10400	4325
51024	Halls Head – Erskine	8822	9225	18047	7690
51025	Mandurah	4406	4659	9065	5347
51026	Mandurah – East	2640	2510	5150	2654
51027	Mandurah – North	6432	6639	13071	5036
51028	Mandurah – South	4642	5093	9735	4591
51029	Pinjarra	4180	4149	8329	2577
51030	City Beach	3387	3428	6815	2458
51031	Claremont (WA)	3851	4261	8112	3545
51032	Cottesloe	3924	4094	8018	3190
51033	Floreat	3819	3862	7681	2635
51034	Mosman Park – Peppermint Grove	5024	5804	10828	4520
51035	Nedlands – Dalkeith – Crawley	9206	9640	18846	6640
51036	Swanbourne – Mount Claremont	4172	4290	8462	3114
51037	Kings Park (WA)	20	14	34	0
51038	Mount Hawthorn – Leederville	5437	5494	10931	4469
51039	Mount Lawley – Inglewood	8384	8888	17272	7488
51040	North Perth	4526	4565	9091	3767
51041	Perth City	15577	12401	27978	10207
51042	Subiaco – Shenton Park	7889	8233	16122	6382
51043	Wembley - West Leederville – Glendalough	8803	8981	17784	8022
51044	Bassendean - Eden Hill – Ashfield	7621	7558	15179	6379
51045	Bayswater – Embleton – Bedford	11159	11389	22548	9380
51046	Maylands	7006	6239	13245	6856
51047	Morley	10900	10765	21665	7873
51048	Noranda	4235	4373	8608	3114
51049	Chidlow	2866	1402	4268	900
51050	Glen Forrest – Darlington	3671	3739	7410	2723
51051	Helena Valley – Koongamia	2409	2457	4866	1795
51052	Malmalling – Reservoir	6	10	16	0
51053	Mundaring	6634	6635	13269	4590
51054	Swan View - Greenmount – Midvale	6279	6318	12597	4838
51055	Avon Valley National Park	0	0	0	0
51056	Ballajura	10130	10181	20311	6530

SA2_5DIG11	SA2_NAME 2011	Total_M_2011	Total_F_2011	Total_P_2011	Dwelling-2011
51057	Beechboro	8102	7953	16055	5163
51058	Bullsbrook	2261	2337	4598	1312
51059	Ellenbrook	11991	12410	24401	8037
51060	Gidgegannup	1363	1304	2667	613
51061	Hazelmere – South Guildford	1931	1857	3788	1455
51062	Lockridge – Kiara	4366	4197	8563	2918
51063	Malaga	6	6	12	0
51064	Melaleuca – Lexia	0	0	0	0
51065	Middle Swan – Herne Hill	2807	2707	5514	1449
51066	Midland – Guildford	5097	4983	10080	4278
51067	Stratton – Jane Brook	3522	3535	7057	2389
51068	The Vines	2869	2798	5667	1491
51069	Walyunga National Park	0	0	0	0
51070	Craigie – Beldon	5167	5007	10174	4130
51071	Currambine – Kinross	7371	7429	14800	4785
51072	Duncraig	7991	8035	16026	5656
51073	Greenwood – Warwick	7077	7124	14201	5371
51074	Heathridge – Connolly	5515	5530	11045	4224
51075	Hillarys	5738	5685	11423	3885
51076	Iluka – Burns Beach	3363	3301	6664	2064
51077	Joondalup – Edgewater	7139	7392	14531	5192
51078	Kingsley	6758	7211	13969	5070
51079	Mullaloo – Kallaroo	5860	5931	11791	4309
51080	Ocean Reef	4373	4326	8699	2831
51081	Padbury	4446	4436	8882	3376
51082	Sorrento – Marmion	5019	5185	10204	3714
51083	Woodvale	4808	4988	9796	3207
51084	Balcatta – Hamersley	7844	8017	15861	6790
51085	Balga – Mirrabooka	9668	9524	19192	6955
51086	Dianella	12052	12791	24843	10033
51087	Herdsman	0	0	0	0
51088	Innaloo – Doubleview	7825	8400	16225	7367
51089	Karrinyup – Gwelup – Carine	9735	10439	20174	7311
51090	Nollamara – Westminster	7973	8106	16079	7080
51091	Osborne Park Industrial	7	2	9	0
51092	Scarborough	8041	7489	15530	7541
51093	Stirling – Osborne Park	7043	6980	14023	5720
51094	Trigg - North Beach – Watermans Bay	3688	3779	7467	3182

SA2_5DIG11	SA2_NAME 2011	Total_M_2011	Total_F_2011	Total_P_2011	Dwelling-2011
51095	Tuart Hill – Joondanna	5810	6221	12031	6167
51096	Wembley Downs – Churchlands – Woodlands	6732	6698	13430	5224
51097	Yokine – Coolbinia – Menora	7660	8097	15757	7208
51098	Alexander Heights – Koondoola	6236	6082	12318	4152
51099	Butler – Merriwa – Ridgewood	9881	10297	20178	7176
51100	Carramar	5783	6049	11832	3548
51101	Clarkson	6130	6160	12290	4336
51102	Girrawheen	4453	4321	8774	3378
51103	Madeley – Darch – Landsdale	9988	10056	20044	6315
51104	Marangaroo	5466	5742	11208	3718
51105	Mindarie – Quinns Rocks – Jindalee	9125	9320	18445	5974
51106	Neerabup National Park	0	0	0	0
51107	Tapping – Ashby – Sinagra	6603	6616	13219	4020
51108	Wanneroo	12026	12185	24211	8034
51109	Yanchep	3908	3854	7762	3065
51110	Armadale – Wungong – Brookdale	8346	8609	16955	6881
51111	Ashendon – Lesley	0	0	0	0
51112	Camillo – Champion Lakes	2798	2713	5511	2123
51113	Forrestdale – Harrisdale – Piara Waters	3908	3835	7743	2691
51114	Kelmscott	5356	5287	10643	4254
51115	Mount Nasura – Mount Richon – Bedfordale	3868	3821	7689	2861
51116	Roleystone	3656	3548	7204	2480
51117	Seville Grove	4852	4798	9650	3280
51118	Belmont – Ascot – Redcliffe	7205	6899	14104	5720
51119	East Victoria Park – Carlisle	8189	7834	16023	7003
51120	Kewdale Commercial	0	0	0	0
51121	Perth Airport	56	9	65	0
51122	Rivervale – Kewdale – Cloverdale	11779	11410	23189	9762
51123	Victoria Park – Lathlain – Burswood	7672	6923	14595	6835
51124	Bentley – Wilson – St James	10411	10508	20919	8124
51125	Canning Vale – West	5286	5432	10718	3242
51126	Canning Vale Commercial	2	1	3	0
51127	Cannington – Queens Park	8271	7587	15858	5733
51128	Parkwood – Ferndale – Lynwood	7158	7165	14323	5722
51129	Riverton – Shelley – Rossmoyne	6771	7214	13985	5019
51130	Welshpool	22	7	29	0
51131	Willetton	9180	9195	18375	6318
51132	Beckenham – Kenwick – Langford	9611	8973	18584	6787

SA2_5DIG11	SA2_NAME 2011	Total_M_2011	Total_F_2011	Total_P_2011	Dwelling-2011
51133	Canning Vale – East	11236	10449	21685	6605
51134	Gosnells	10032	10074	20106	8078
51135	Huntingdale – Southern River	7673	7601	15274	5104
51136	Maddington – Orange Grove – Martin	6335	6121	12456	4750
51137	Thornlie	12160	12170	24330	8781
51138	Forrestfield – Wattle Grove	8356	8499	16855	6422
51139	High Wycombe	6217	6145	12362	4544
51140	Kalamunda – Maida Vale – Gooseberry Hill	7623	7737	15360	6015
51141	Lesmurdie – Bickley – Carmel	5937	5978	11915	3964
51142	Byford	4246	4225	8471	2891
51143	Mundijong	3000	2918	5918	1938
51144	Serpentine – Jarrahdale	2241	1919	4160	1263
51145	Como	6789	7594	14383	7201
51146	Manning – Waterford	5887	5824	11711	4149
51147	South Perth – Kensington	8890	8710	17600	7748
51148	Banjup	7397	7514	14911	4822
51149	Beeliar	3126	3175	6301	2072
51150	Bibra Industrial	11	6	17	0
51151	Bibra Lake	0	0	0	0
51152	Coogee	3995	4018	8013	2758
51153	Coolbellup	4013	4130	8143	3422
51154	Hamilton Hill	5241	5263	10504	4536
51155	Henderson	9	3	12	0
51156	Jandakot	1345	1359	2704	898
51157	Jandakot Airport	237	6	243	0
51158	North Coogee	304	288	592	293
51159	South Lake – Cockburn Central	5896	5887	11783	4464
51160	Spearwood	4845	4918	9763	3893
51161	Success – Hammond Park	5734	5715	11449	4135
51162	Wattleup	356	276	632	107
51163	Yangebup	3829	3719	7548	2730
51164	East Fremantle	3634	3809	7443	2995
51165	Fremantle	7183	7149	14332	6276
51166	Fremantle – South	7025	7413	14438	6003
51167	O'Connor (WA)	4	1	5	0
51168	Anketell – Wandi	651	560	1211	374
51169	Bertram – Wellard (West)	4102	4108	8210	2920
51170	Calista	3768	3932	7700	3082

SA2_5DIG11	SA2_NAME 2011	Total_M_2011	Total_F_2011	Total_P_2011	Dwelling-2011
51171	Casuarina – Wellard (East)	1401	663	2064	466
51172	Hope Valley – Postans	52	78	130	26
51173	Kwinana Industrial	8	5	13	0
51174	Parmelia – Orelia	5698	5671	11369	4503
51175	Applecross – Ardross	5510	5891	11401	4487
51176	Bateman	2012	1998	4010	1358
51177	Bicton – Palmyra	6528	7274	13802	6339
51178	Booragoon	7097	7734	14831	6084
51179	Bull Creek	3912	4161	8073	2934
51180	Leeming	5960	5882	11842	4028
51181	Melville	7816	8565	16381	6440
51182	Murdoch – Kardinya	6338	6589	12927	4261
51183	Willagee	2388	2651	5039	2049
51184	Winthrop	3350	3326	6676	2060
51185	Baldivis	8628	8636	17264	5667
51186	Cooloongup	4479	4600	9079	3645
51187	Port Kennedy	7355	7426	14781	4879
51188	Rockingham	8025	7738	15763	7202
51189	Rockingham Lakes	9	7	16	0
51190	Safety Bay – Shoalwater	5893	5984	11877	5592
51191	Singleton – Golden Bay – Secret Harbour	8331	7965	16296	5617
51192	Waikiki	6211	6322	12533	4666
51193	Warnbro	5909	5897	11806	4301

Table 4.2: Non-residential information – used for transport model

SA2_5DIG11	SA2_NAME11	Number of primary and secondary students 2011	Number of tertiary and TAFE students 2011	Number of people employed 2011	Retail floor space (NLA m^2)	Office floor space (NLA m^2)	Show-room (NLA m^2)	Industry (NLA m^2)
51021	Dawesville – Bouvard	1395	192	231	0	0	0	0
51022	Falcon – Wannanup	1678	286	315	15064	445	357	0
51023	Greenfields	2352	369	175	7042	5400	24865	421648
51024	Halls Head – Erskine	4133	717	730	10000	842	973	28038
51025	Mandurah	1704	346	192	78209	14295	45383	205896
51026	Mandurah – East	1057	146	238	0	0	0	0
51027	Mandurah – North	3273	524	422	6964	192	106	0
51028	Mandurah – South	1972	328	215	0	0	7500	0
51029	Pinjarra	1993	218	279	4850	0	1300	0
51030	City Beach	1721	496	697	8587	2270	32	188
51031	Claremont (WA)	1733	783	540	89917	115338	18088	12917
51032	Cottesloe	1874	650	700	26507	14332	991	4767
51033	Floreat	1901	638	597	39356	10749	205	73
51034	Mosman Park – Peppermint Grove	2605	993	795	12702	14339	955	1225
51035	Nedlands – Dalkeith – Crawley	3853	3525	1404	52556	319802	4712	61162
51036	Swanbourne – Mount Claremont	2040	690	641	579	189	0	0
51037	Kings Park (WA)	9	0	5	0	0	0	0
51038	Mount Hawthorn – Leederville	2233	864	535	84581	169742	16422	75020
51039	Mount Lawley – Inglewood	3228	1962	939	111303	80293	84286	57963
51040	North Perth	1633	739	455	41137	44984	5437	33297
51041	Perth City	5154	2961	1124	478248	2274625	19187	168709
51042	Subiaco – Shenton Park	2931	1490	950	108622	418711	15403	56206
51043	Wembley – West Leederville – Glendalough	3542	1619	775	48874	157165	3175	32157
51044	Bassendean – Eden Hill – Ashfield	2993	905	467	22298	106457	12399	332048
51045	Bayswater – Embleton – Bedford	4350	1493	749	11471	40961	2548	13249
51046	Maylands	2238	1206	400	39459	27372	3478	9049
51047	Morley	4152	1341	685	127716	195730	30578	332573
51048	Noranda	1602	550	505	10464	4665	677	413
51049	Chidlow	2065	120	112	3453	4828	238	24891
51050	Glen Forrest – Darlington	1759	469	405	3126	5652	1797	4645

SA2_5DIG11	SA2_NAME11	Number of primary and secondary students 2011	Number of tertiary and TAFE students 2011	Number of people employed 2011	Retail floor space (NLA m^2)	Office floor space (NLA m^2)	Show-room (NLA m^2)	Industry (NLA m^2)
51051	Helena Valley – Koongamia	1189	236	215	108	0	0	0
51052	Malmalling – Reservoir	4	0	0	0	0	0	0
51053	Mundaring	3265	678	691	27411	82967	9224	71746
51054	Swan View – Greenmount – Midvale	2663	558	353	8174	2343	6280	17218
51055	Avon Valley National Park	0	0	0	0	0	0	0
51056	Ballajura	5004	1257	617	10834	22434	708	689
51057	Beechboro	4046	891	426	10301	12188	393	6889
51058	Bullsbrook	1186	154	247	7944	4673	3148	41273
51059	Ellenbrook	6514	1064	683	775	2169	0	0
51060	Gidgegannup	683	109	212	0	0	0	0
51061	Hazelmere – South Guildford	789	193	134	14520	2363	2479	29928
51062	Lockridge – Kiara	1964	407	207	4117	10997	3128	432167
51063	Malaga	3	0	0	9686	7725	1849	59579
51064	Melaleuca – Lexia	0	0	0	0	0	0	0
51065	Middle Swan – Herne Hill	1350	243	209	4909	4494	689	110246
51066	Midland – Guildford	2216	505	230	229813	606867	116849	684806
51067	Stratton – Jane Brook	1810	324	166	4186	1859	1523	0
51068	The Vines	1391	271	473	7265	0	98	18001
51069	Walyunga National Park	0	0	0	0	0	0	0
51070	Craigie – Beldon	1937	605	249	26893	6647	975	2433
51071	Currambine – Kinross	3596	981	494	34930	10615	151	387
51072	Duncraig	3214	1056	807	12315	12156	1556	2527
51073	Greenwood - Warwick	2609	846	478	86662	34621	1294	4512
51074	Heathridge – Connolly	2327	693	398	8364	7235	1285	1382
51075	Hillarys	2564	785	834	93926	26078	35681	20610
51076	Iluka – Burns Beach	1665	457	479	0	0	0	0
51077	Joondalup – Edgewater	2898	1507	461	105205	449012	13381	26934
51078	Kingsley	2883	849	618	15787	7023	1955	7661
51079	Mullaloo – Kallaroo	2557	776	680	7366	884	1574	387
51080	Ocean Reef	2045	613	482	7948	18897	1463	1620
51081	Padbury	1727	525	272	8324	9623	3378	1316
51082	Sorrento – Marmion	2207	733	795	7738	2447	2083	1971

SA2_5DIG11	SA2_NAME11	Number of primary and secondary students 2011	Number of tertiary and TAFE students 2011	Number of people employed 2011	Retail floor space (NLA m^2)	Office floor space (NLA m^2)	Show-room (NLA m^2)	Industry (NLA m^2)
51083	Woodvale	2137	750	427	21052	10637	2394	8849
51084	Balcatta – Hamersley	2865	927	560	32523	25923	14465	21956
51085	Balga – Mirrabooka	5349	1233	282	14899	15237	1843	2815
51086	Dianella	4814	1731	1284	100725	195088	19233	97505
51087	Herdsman	0	0	0	0	0	0	0
51088	Innaloo – Doubleview	3105	1149	595	18255	59036	7140	1955
51089	Karrinyup – Gwelup – Carine	4411	1218	1227	53444	45464	4238	9660
51090	Nollamara – Westminster	3234	1248	309	29031	33820	11977	36561
51091	Osborne Park Industrial	0	0	0	70519	198453	74206	695061
51092	Scarborough	2921	1080	694	55883	24440	15548	11990
51093	Stirling – Osborne Park	2766	972	790	56421	225376	6756	80160
51094	Trigg – North Beach – Watermans Bay	1469	423	570	32594	8735	6733	14038
51095	Tuart Hill – Joondanna	1952	1004	352	5205	10487	0	1557
51096	Wembley Downs – Churchlands – Woodlands	2895	1109	811	4162	1658	3148	2399
51097	Yokine – Coolbinia – Menora	2929	1247	767	33574	166051	18964	72130
51098	Alexander Heights – Koondoola	2953	754	353	11711	95383	2714	6599
51099	Butler – Merriwa – Ridgewood	5545	873	365	229	0	1885	0
51100	Carramar	3227	634	386	3719	0	1131	14518
51101	Clarkson	3161	690	218	0	0	0	0
51102	Girrawheen	2173	526	121	55899	29711	7294	55712
51103	Madeley – Darch – Landsdale	5076	1098	950	3513	9514	21957	0
51104	Marangaroo	2677	608	285	2137	6377	0	0
51105	Mindarie – Quinns– Rocks - Jindalee	5161	914	884	10652	4798	3694	0
51106	Neerabup National Park	0	0	0	0	0	0	0
51107	Tapping – Ashby – Sinagra	3245	645	492	0	0	0	0
51108	Wanneroo	5044	1225	907	46242	105753	34416	388710
51109	Yanchep	2098	247	281	42127	37019	19790	140295
51110	Armadale – Wungong – Brookdale	4204	654	194	70521	148725	10000	19198
51111	Ashendon – Lesley	0	0	0	0	0	0	0

SA2_5DIG11	SA2_NAME11	Number of primary and secondary students 2011	Number of tertiary and TAFE students 2011	Number of people employed 2011	Retail floor space (NLA m^2)	Office floor space (NLA m^2)	Show-room (NLA m^2)	Industry (NLA m^2)
51112	Camillo – Champion Lakes	1321	264	106	5717	2233	1177	5471
51113	Forrestdale – Harrisdale – Piara Waters	1616	463	283	234	4466	178	4651
51114	Kelmscott	2294	474	250	26840	41560	11199	58470
51115	Mount Nasura – Mount Richon – Bedfordale	1627	365	404	2367	9620	6024	41168
51116	Roleystone	1485	397	441	16195	2909	1988	16115
51117	Seville Grove	2565	427	165	151	20376	0	5836
51118	Belmont – Ascot – Redcliffe	2996	787	454	103132	660706	43621	872341
51119	East Victoria Park – Carlisle	2899	1729	459	92584	120541	8935	33392
51120	Kewdale Commercial	0	0	0	411	0	0	0
51121	Perth Airport	52	0	0	0	0	0	0
51122	Rivervale – Kewdale – Cloverdale	4694	1650	563	21049	66438	2548	73990
51123	Victoria Park – Lathlain – Burswood	2642	1658	548	115132	316360	18877	78900
51124	Bentley – Wilson – St James	3998	4001	355	34528	120053	22486	245329
51125	Canning Vale – West	2508	888	525	1536	15389	349	4222
51126	Canning Vale Commercial	0	0	0	0	0	137	2973
51127	Cannington – Queens Park	3338	1715	378	171126	609533	70654	2048683
51128	Parkwood - Ferndale – Lynwood	2508	1043	287	47127	20148	672	4014
51129	Riverton – Shelley – Rossmoyne	3125	1326	660	74529	90988	46282	190250
51130	Welshpool	0	0	4	0	0	0	0
51131	Willetton	3897	1680	712	0	0	0	0
51132	Beckenham – Kenwick – Langford	4395	1180	380	22031	122905	10994	97178
51133	Canning Vale – East	6129	1567	780	1465	768	0	0
51134	Gosnells	4846	833	321	59947	80075	41364	145219
51135	Huntingdale – Southern River	3654	835	482	2772	0	0	0
51136	Maddington – Orange Grove – Martin	2826	567	390	66297	61865	34452	160797
51137	Thornlie	5323	1409	542	39043	19072	2010	2918
51138	Forrestfield – Wattle Grove	3640	764	493	30615	94531	3727	87827
51139	High Wycombe	2854	524	352	14534	2967	426	2779

SA2_5DIG11	SA2_NAME11	Number of primary and secondary students 2011	Number of tertiary and TAFE students 2011	Number of people employed 2011	Retail floor space (NLA m^2)	Office floor space (NLA m^2)	Show-room (NLA m^2)	Industry (NLA m^2)
51140	Kalamunda – Maida Vale – Gooseberry Hill	3069	824	868	41397	90581	5283	97021
51141	Lesmurdie – Bickley – Carmel	2963	669	672	3824	472	421	1962
51142	Byford	2029	392	334	44660	96937	2648	40934
51143	Mundijong	1467	266	435	19490	69099	774	23634
51144	Serpentine – Jarrahdale	1142	130	220	20304	23921	1381	50972
51145	Como	2293	1594	615	13376	10439	1049	2062
51146	Manning – Waterford	2515	1657	603	7270	211	230	446
51147	South Perth – Kensington	3533	1708	1099	24114	45430	1072	4341
51148	Banjup	3812	845	595	1161	0	0	75791
51149	Beeliar	1514	308	209	0	0	0	75791
51150	Bibra Industrial	0	0	0	930	0	0	75791
51151	Bibra Lake	0	0	0	0	0	0	0
51152	Coogee	1688	429	418	96	2430	0	75791
51153	Coolbellup	1633	562	218	18055	24764	719	107614
51154	Hamilton Hill	2179	628	245	97067	186424	25001	179213
51155	Henderson	0	0	0	0	0	0	75791
51156	Jandakot	551	168	206	0	0	0	75791
51157	Jandakot Airport	218	0	0	0	0	0	0
51158	North Coogee	153	44	62	0	0	0	75791
51159	South Lake – Cockburn Central	2376	753	294	15592	127009	12602	84650
51160	Spearwood	1809	456	265	1228	0	1198	80092
51161	Success – Hammond Park	2526	723	300	7688	24614	779	79447
51162	Wattleup	109	25	53	4807	23994	6613	94541
51163	Yangebup	1785	423	185	3933	7840	2995	79662
51164	East Fremantle	1642	525	530	20599	19890	2104	13048
51165	Fremantle	2497	1169	678	203053	406059	41576	437492
51166	Fremantle – South	2757	1000	541	31349	29088	13723	186077
51167	O'Connor (WA)	0	0	0	2264	954	171	16685
51168	Anketell – Wandi	279	87	98	0	0	0	76562
51169	Bertram – Wellard (West)	2012	411	164	0	0	0	76562
51170	Calista	2105	281	68	5032	8642	2251	98288
51171	Casuarina – Wellard (East)	931	73	101	0	0	0	76562
51172	Hope Valley – Postans	41	0	7	0	0	0	76562

SA2_5DIG11	SA2_NAME11	Number of primary and secondary students 2011	Number of tertiary and TAFE students 2011	Number of people employed 2011	Retail floor space (NLA m^2)	Office floor space (NLA m^2)	Show-room (NLA m^2)	Industry (NLA m^2)
51173	Kwinana Industrial	0	0	0	0	0	0	76562
51174	Parmelia – Orelia	2741	444	104	47370	176573	13009	108929
51175	Applecross – Ardross	2509	1026	954	30149	96993	9880	57405
51176	Bateman	825	428	176	0	452	0	0
51177	Bicton – Palmyra	2623	897	596	21288	20465	7965	13044
51178	Booragoon	2850	1235	913	5350	3034	1665	8017
51179	Bull Creek	1546	726	317	11223	18920	950	1456
51180	Leeming	2320	1047	500	4054	19552	990	2629
51181	Melville	3519	1103	957	147795	76947	17986	71229
51182	Murdoch – Kardinya	2310	1818	558	18148	5013	400	7291
51183	Willagee	1122	311	131	6704	4299	1015	3303
51184	Winthrop	1356	704	391	4802	7014	0	435
51185	Baldivis	4250	750	546	907	0	351	0
51186	Cooloongup	1955	334	91	3600	1661	401	1142
51187	Port Kennedy	4317	669	272	1997	4300	0	0
51188	Rockingham	2932	653	327	156389	272651	76022	498852
51189	Rockingham Lakes	9	0	0	0	0	0	0
51190	Safety Bay – Shoalwater	2255	504	273	22754	11835	5339	67675
51191	Singleton – Golden Bay – Secret Harbour	4701	771	533	2565	1585	751	0
51192	Waikiki	3094	559	226	1067	0	0	0
51193	Warnbro	2852	549	171	23536	3863	4207	5078

4.9 Summary

This chapter discussed the data preparation and analysis for the modelling, which was in turn one of the most sensitive and difficult steps in preparation of this thesis.

It is noted that data acquisition and processing is an indispensable step in the process of developing a transport model, and it normally takes up to several months, even years for a team of researchers. It is hereby acknowledged that this author undertook a significant amount of work with no assistance to put together all the information provided in Tables 4.1 and 4.2 and Appendix B.

The author also acknowledges the governmental agencies who provided the information and is appreciative of them doing so in a kindly and timely manner.

5 WORK TRIP-LENGTH CALIBRATION

As discussed in Chapters 2 and 3, it is aimed to calibrate the work-trip lengths based on the available actual surveyed data provided by the DoPLH and ABS. Therefore, the outcome of the 2011 household travel survey and PARTS data have been used to calibrate the trip length for home-based work trips. Furthermore, the proposed function which will provide the best curve-fitting results will be used to estimate the associated parameters for home-based work trips. Finally, the proposed deterrence function will be introduced to the Gravity Model to distribute the work trips between the Origin and Destination (OD) zones in the developed transport model.

5.1 Actual Home-Based Work-Trips Data

In liaison with the DoPLH, it was established that a detailed home-based daily work travel survey had been undertaken at the SA2 level for the Base Year (Year 2011). Therefore, this information was obtained in a Microsoft Excel spreadsheet which demonstrated the number of actual work trips between each of the two zones in SA2. The information was provided for all WA, which was then clipped to only include the extent of the modelling area (metropolitan and Peel region). It is important to note that the work trips provided by the DoPLH were based on person trips and not vehicular trips.

As it was not possible to present all the associated trips between each of the two zones in this document (due to the size of the spreadsheet which results in a 173*173 table), it has been attempted to show a sample of the raw information in tables Tables 5.1 to 5.4. For example, the first 20 zones at the SA2 level (zones 51021 to 51040 incl.) have been selected to show their relative work trips to and from the rest of the zones. It is noted that these tables also show the internal work trips, which means the work trips that the ODs occurred within the same suburb.

In the following tables, the SA2 zone numbers and their respective suburb names are provided in the first two columns and rows, and the total number of actual surveyed person work trips between each of the two zones is provided within each cell.

Table 5.1: Actual surveyed home-based work person trips at SA2 level – work trips between zones 51021 and 51040

		51021	51022	51023	51024	51025	51026	51027	51028	51029	51030	51031	51032	51033	51034	51035	51036	51037	51038	51039	51040
SA 2 zones	Suburbs	Dawesville - Bouvard	Falcon - Wannanup	Greenfields	Halls Head - Erskine	Mandurah	Mandurah - East	Mandurah - North	Mandurah - South	Pinjarra	City Beach	Claremont (WA)	Cottesloe	Floreat	Mosman Park - Peppermint Grove	Nedlands - Dalkeith - Crawley	Swanbourne - Mount Claremont	Kings Park (WA)	Mount Hawthorn - Leederville	Mount Lawley - Inglewood	North Perth
51021	Dawesville - Bouvard	337	186	145	86	300	7	36	24	99	0	0	0	0	0	8	0	0	4	0	0
51022	Falcon - Wannanup	37	522	192	161	483	17	41	50	132	0	3	0	0	0	11	0	0	7	0	0
51023	Greenfields	13	57	676	92	723	36	92	82	202	0	0	0	3	0	9	0	0	4	0	0
51024	Halls Head - Erskine	44	205	522	1066	1392	37	119	124	418	0	9	0	0	0	13	0	0	10	6	0
51025	Mandurah	12	60	231	85	931	23	77	64	137	0	0	0	0	0	7	0	0	0	0	0
51026	Mandurah - East	0	16	129	42	247	290	33	30	278	0	0	0	0	0	10	0	0	3	0	0
51027	Mandurah - North	10	56	415	125	945	28	617	85	263	0	3	0	0	6	14	3	0	3	0	0
51028	Mandurah - South	11	60	265	96	681	17	81	315	173	0	0	0	0	3	16	0	0	8	0	0
51029	Pinjarra	5	29	142	28	240	38	39	32	1258	0	0	0	0	0	4	0	0	0	0	0
51030	City Beach	0	0	0	0	0	0	0	0	0	444	50	23	53	19	116	42	8	36	12	11
51031	Claremont (WA)	0	0	0	0	0	0	0	0	0	9	632	83	21	70	300	85	4	24	22	0
51032	Cottesloe	0	0	0	0	0	0	0	0	0	10	179	532	7	94	224	74	12	24	14	5
51033	Floreat	0	0	0	0	0	0	0	0	0	23	80	23	453	25	212	68	9	74	26	9
51034	Mosman Park - Peppermint Grove	0	0	9	0	0	0	0	0	0	5	202	175	10	808	295	58	8	26	18	12
51035	Nedlands - Dalkeith - Crawley	0	5	4	0	10	0	0	0	0	4	378	73	18	103	2187	99	23	70	41	13
51036	Swanbourne - Mount Claremont	0	0	0	0	0	0	0	0	0	8	248	65	26	50	252	621	7	25	21	5
51037	Kings Park (WA)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
51038	Mount Hawthorn - Leederville	0	0	0	0	0	0	0	0	0	6	52	20	19	16	235	37	14	725	73	67
51039	Mount Lawley - Inglewood	0	0	0	0	3	0	0	0	0	5	75	20	3	22	260	30	15	127	1168	97
51040	North Perth	0	0	0	0	0	0	0	0	0	4	30	10	6	14	169	26	4	136	108	490

Table 5.2: Actual surveyed home-based work person trips at SA2 level – work trips between zones 51021 and 51040 and 51041 and 51060

		51041	51042	51043	51044	51045	51046	51047	51048	51049	51050	51051	51052	51053	51054	51055	51056	51057	51058	51059	51060
SA 2 zones	Suburbs	Perth City	Subiaco - Shenton Park	Wembley - West Leederville - Glendalough	Bassendean - Eden Hill - Ashfield	Bayswater - Embleton - Bedford	Maylands	Morley	Noranda	Chidlow	Glen Forrest - Darlington	Helena Valley - Koongamia	Malmalling - Reservoir	Mundaring	Swan View - Greenmount - Midvale	Avon Valley National Park	Ballajura	Beechboro	Bullsbrook	Ellenbrook	Gidgegannup
51021	Dawesville - Bouvard	92	10	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51022	Falcon - Wannanup	129	11	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51023	Greenfields	114	11	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51024	Halls Head - Erskine	267	33	14	5	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51025	Mandurah	125	13	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51026	Mandurah - East	74	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51027	Mandurah - North	282	40	10	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51028	Mandurah - South	147	10	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51029	Pinjarra	50	4	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51030	City Beach	664	237	103	4	8	0	6	3	0	0	0	0	4	0	0	3	0	0	0	0
51031	Claremont (WA)	878	266	61	7	4	4	0	0	0	0	0	0	0	4	0	3	0	0	0	8
51032	Cottesloe	956	242	61	11	13	3	11	0	0	0	0	0	0	0	0	4	0	0	0	5
51033	Floreat	939	338	167	11	3	3	7	0	0	0	0	0	0	0	0	0	0	0	3	0
51034	Mosman Park - Peppermint Grove	982	273	68	11	15	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
51035	Nedlands - Dalkeith - Crawley	2033	582	147	11	14	9	15	0	0	0	0	0	0	3	0	0	4	0	0	0
51036	Swanbourne - Mount Claremont	896	332	95	4	4	4	8	0	0	0	0	0	0	0	0	0	0	0	4	0
51037	Kings Park (WA)	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51038	Mount Hawthorn - Leederville	1700	334	128	22	22	7	27	6	0	0	0	0	0	3	0	3	4	7	9	0
51039	Mount Lawley - Inglewood	2983	407	115	72	164	79	162	17	0	3	0	0	15	14	0	17	3	9	16	0
51040	North Perth	1470	253	82	14	32	13	42	11	0	6	0	0	4	11	0	7	0	9	0	0

Table 5.3: Actual surveyed home-based work person trips at SA2 level – work trips between zones 51021 and 51040 and 51061 and 51080

		51061	51062	51063	51064	51065	51066	51067	51068	51069	51070	51071	51072	51073	51074	51075	51076	51077	51078	51079	51080
SA 2 zones	Suburbs	Hazelmere - South Guildford	Lockridge - Kiara	Malaga	Melaleuca - Lexia	Middle Swan - Herne Hill	Midland - Guildford	Stratton - Jane Brook	The Vines	Walyunga National Park	Craigie - Beldon	Currambine - Kinross	Duncraig	Greenwood - Warwick	Heathridge - Connolly	Hillarys	Iluka - Burns Beach	Joondalup - Edgewater	Kingsley	Mullaloo - Kallaroo	Ocean Reef
51021	Dawesville - Bouvard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51022	Falcon - Wannanup	6	3	8	0	0	4	0	0	0	0	0	0	0	0	0	0	3	0	0	0
51023	Greenfields	6	0	8	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51024	Halls Head - Erskine	3	0	7	0	0	5	0	0	0	0	0	0	0	0	0	0	3	0	0	0
51025	Mandurah	7	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51026	Mandurah - East	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51027	Mandurah - North	5	0	9	0	0	11	0	0	0	0	0	0	0	0	0	0	9	0	0	0
51028	Mandurah - South	9	0	4	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51029	Pinjarra	11	0	4	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51030	City Beach	7	0	7	0	0	16	0	0	0	0	0	15	8	0	7	0	42	0	0	0
51031	Claremont (WA)	3	0	7	0	0	7	0	0	0	0	0	4	7	0	0	0	12	0	0	0
51032	Cottesloe	6	0	10	0	0	8	0	0	0	0	0	5	0	0	5	0	14	0	0	0
51033	Floreat	5	0	24	0	3	3	0	0	0	0	0	18	8	0	7	0	20	0	0	0
51034	Mosman Park - Peppermint Grove	3	0	14	0	0	14	0	6	0	0	0	4	3	0	0	0	14	0	0	0
51035	Nedlands - Dalkeith - Crawley	8	0	33	0	4	15	0	0	0	3	0	15	8	0	9	0	41	5	4	0
51036	Swanbourne - Mount Claremont	0	0	23	0	0	15	0	0	0	4	0	0	4	0	3	0	25	4	4	4
51037	Kings Park (WA)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51038	Mount Hawthorn - Leederville	8	4	67	0	9	27	0	0	0	5	0	5	14	0	12	0	63	8	4	0
51039	Mount Lawley - Inglewood	29	18	123	0	25	100	4	0	0	5	0	10	18	0	14	0	56	11	0	0
51040	North Perth	7	0	65	0	9	33	0	0	0	0	0	0	13	0	10	0	35	0	0	4

Table 5.4: Actual surveyed home-based work person trips at SA2 level – work trips between zones 51021 and 51040 and 51081 and 51100

		51081	51082	51083	51084	51085	51086	51087	51088	51089	51090	51091	51092	51093	51094	51095	51096	51097	51098	51099	51100
SA 2 zones	Suburbs	Padbury	Sorrento - Marmion	Woodvale	Balcatta - Hamersley	Balga - Mirrabooka	Dianella	Herdsman	Innaloo - Doubleview	Karrinyup - Gwelup - Carine	Nollamara - Westminster	Osborne Park Industrial	Scarborough	Stirling - Osborne Park	Trigg - North Beach - Watermans Bay	Tuart Hill - Joondanna	Wembley Downs - Churchlands - Woodlands	Yokine - Coolbinia - Menora	Alexander Heights - Koondoola	Butler - Merriwa - Ridgewood	Carramar
51021	Dawesville - Bouvard	0	0	0	3	0	0	0	0	3	0	16	0	0	0	0	0	0	0	0	0
51022	Falcon - Wannanup	0	0	0	7	0	0	0	0	0	0	21	4	0	0	0	0	5	0	0	0
51023	Greenfields	0	0	0	3	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0
51024	Halls Head - Erskine	0	0	0	16	0	0	0	0	0	0	34	0	5	0	0	0	0	0	0	0
51025	Mandurah	0	0	0	3	0	0	0	0	0	0	16	0	6	0	0	0	0	0	0	0
51026	Mandurah - East	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
51027	Mandurah - North	0	0	0	8	0	0	0	0	3	0	18	0	0	0	0	0	3	0	0	0
51028	Mandurah - South	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0
51029	Pinjarra	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
51030	City Beach	0	0	5	32	0	6	0	33	21	8	133	26	29	7	0	47	13	0	0	0
51031	Claremont (WA)	4	3	0	21	4	16	0	3	5	0	86	4	15	0	4	10	4	4	0	0
51032	Cottesloe	0	6	5	20	0	4	0	8	4	0	82	4	23	0	5	13	0	0	0	0
51033	Floreat	5	4	0	25	4	8	0	24	20	3	138	18	36	3	12	58	10	0	0	0
51034	Mosman Park - Peppermint Grove	0	3	0	32	0	6	0	11	7	0	90	10	21	0	0	10	0	0	0	4
51035	Nedlands - Dalkeith - Crawley	4	5	0	33	4	18	0	21	27	3	140	3	35	0	4	27	12	0	0	3
51036	Swanbourne - Mount Claremont	0	0	0	22	0	5	0	14	13	0	90	4	17	7	0	16	4	0	0	0
51037	Kings Park (WA)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51038	Mount Hawthorn - Leederville	4	4	5	63	4	29	0	37	34	15	241	12	64	8	14	41	28	9	4	0
51039	Mount Lawley - Inglewood	0	4	8	84	20	86	0	34	32	9	217	11	63	0	16	31	49	11	3	5
51040	North Perth	0	0	4	50	4	30	0	9	25	4	138	5	49	3	16	13	41	0	0	0

Note: Columns and rows to be continued to zone number 51193.

The distances between each of the two zones within the SA2 level were extracted from the EMME transportation model in accordance with the following methodology:

EMME command

In SOLA assignment (5.23) there is an option "Link attribute for path analysis" and below is a portion of a macro that executes this operation:

[…]

~#Link attribute for path analysis

Length

~#Turn attribute for path analysis

~#Operator to compute path attributes

+

~#Lower, upper threshold for selected paths

~#Select type of O-D attributes: 1=path attributes; 2=selected path attributes;3=selected path attributes weighted by analyzed demand;4=analyzed demand on selected paths

1

~#Demand to be analyzed for class 1 (optional)

~#Matrix to hold O-D attributes for class 1 (optional)

~+|mf1|y|SOLA_Dist|Distances SOLA|~?Q=1|y|0

[…]

Note that in the new versions of EMME this exercise can easily be done through Modeler Tool Path-based traffic analysis. Furthermore, this information was sourced from the EMME forum, of which the author is a participant.

Following the above command in EMME, the distances between each of the two centroids were derived in the form of a zero-diagonal matrix. The distances between the centroids demonstrate the actual distance of travel between each of the two SA2 zones. Again, due to the size of the table (173*173 cell table), only a section of the distance matrix is provided in Table 5.5.

Table 5.5: Matrix of distances between each of the two zones at SA2

	51021	51022	51023	51024	51025	51026	51027	51028	51029	51030
51021	0.00	12.19	24.73	19.08	22.78	28.08	27.27	22.82	41.86	94.75
51022	12.19	0.00	13.74	8.09	11.79	17.09	16.28	11.83	30.87	83.77
51023	24.73	13.74	0.00	9.92	2.57	7.89	7.95	5.22	21.67	79.40
51024	19.08	8.09	9.92	0.00	7.97	13.27	12.46	8.01	27.05	79.95
51025	22.78	11.79	2.57	7.97	0.00	7.98	6.25	3.85	21.76	78.08
51026	28.08	17.09	7.89	13.27	7.98	0.00	13.36	7.17	17.74	84.25
51027	27.27	16.28	7.95	12.46	6.25	13.36	0.00	8.79	26.50	72.61
51028	22.69	11.70	5.22	7.88	3.85	7.17	8.79	0.00	20.95	81.07
51029	41.86	30.87	21.67	27.05	21.76	17.74	26.51	20.95	0.00	94.00
51030	94.75	83.77	80.57	79.95	73.74	85.32	68.44	76.28	94.55	0.00

Note: Columns and rows to be continued to zone number 51193.

Once the actual number of work trips and the actual distances between each of the two zones were available, the next step was to relate the number of trips to the distances of travel.

Conversion of person trips to vehicle trips

'Person trip' is a term which demonstrates the number of trips produced by one person with any mode of transportation, while 'vehicle trip' is a term defined as any trip made by a single motorised vehicle regardless of the number of passengers. It means that if two people are sharing one car for commuting to work, then it is considered as one vehicular trip, but counted as two person trips.

When different modes of transportation such as private car, public transport and taxis are accounted for, the modelling (multimodal transportation model), then person trip is deemed appropriate and should be used as a base for the model development. However, as this research only focuses on motorised vehicles as being the only mode of transport, then vehicle trips are deemed more appropriate. Therefore, and to translate the person trips data provided by the DoPLH to vehicle trips, a 1.08 vehicle occupancy factor has been used to estimate the number of vehicle trips. The 1.08 occupancy factor for work trips is in accordance with the review and analysis of the actual PARTS data. It is noted that different trip purposes have different occupancy factors per vehicle, and the surveyed 1.08 factor for work trips suggests that the person work trips in Perth is relatively similar to the vehicular work trips.

Furthermore, it is noted that this research only focuses on daily trips and not peak-hour trips.

5.2 Home-Based Work Trips – Trip-Length Analysis

To establish the total number of trips with respect to the distance of travel, all the 173 zones were sorted 173 times in rows and columns. The distance of travel between each pair of zones and the actual number of trips were identified through the application of a VLOOKUP command in Microsoft Excel. Then, the summation of all the actual vehicle trips with the same distance of travel were estimated and tabulated into a PIVOT table, as shown in Tables 5.6 to 5.9.

Table 5.6: Total number of actual work trips versus distance of travel – (2-10 km)

Dij (Km)	2	3	4	5	6	7	8	9	10
Sum of Fij (Vpd)	1187	5499	12108	19477	32584	17046	36109	27446	19427

Table 5.7: Total number of actual work trips versus distance of travel – (11-20 km)

Dij (Km)	11	12	13	14	15	16	17	18	19	20
Sum of Fij (Vpd)	24031	24571	30896	26307	17777	20091	20324	19871	20023	15075

Table 5.8: Total number of actual work trips versus distance of travel – (21-30 km)

Dij (Km)	21	22	23	24	25	26	27	28	29	30
Sum of Fij (Vpd)	13159	13417	13035	14296	10897	11897	9159	10688	7739	6540

Table 5.9: Total number of actual work trips versus distance of travel – (31-40 km)

Dij (Km)	31	32	33	34	35	36	37	38	39	40
Sum of Fij (Vpd)	7474	7571	5256	3960	4505	4113	3685	3121	4357	2908

Note that in Tables 5.6 to 5.9, Dij is referred to as the actual distance of travel, and Sum of Fij is referred to as the total number of daily vehicle trips.

Subsequently, the total number of actual daily work trips were also plotted against their respective distance of travel, and the outcome of the analysis is shown in different graphs presented in Figures 5.1 and 5.2 for the purpose of further discussion and assessment.

The graph presented in Figure 5.1 relates to the actual total number of work trips counted for the Perth metropolitan area and Peel region in y-axis (Fij) versus the distances of the trips commuted in x-axis (Dij).

Figure 5.1: Actual work trip volumes per day versus distance of travel

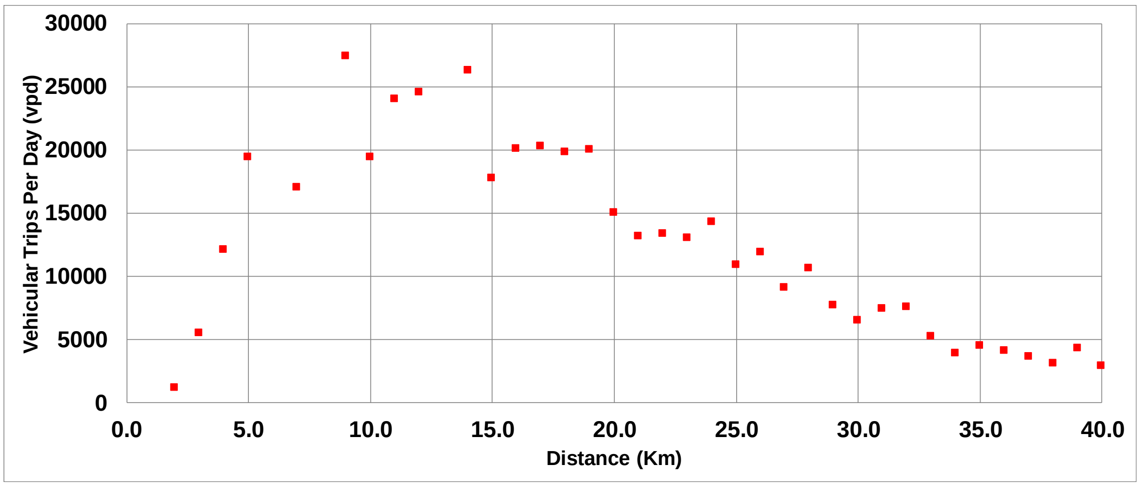


Figure 5.1 contains useful actual information regarding the home-based work trips for commuters to work in Perth. According to this figure, the work trips start to increase from 0 to about 8 km where it reaches its first peak. After that, there is a slight drop in the actual work trip numbers from 8 to 10 km; however, the work trip again starts to increase before it hits its second peak at about 13 km. The total number of work trips between 15 and 19 km is estimated to be in an approximately constant order, and after 20 km the work trips are shown to drop in number. This could potentially show that people in Perth may primarily prefer to drive to their workplaces for distances between 10 and 20 km.

From Figure 5.1 it can also be concluded that for distances of more than 35 km, cars are not the preferred mode of transport, and other modes, such as public transport, are likely to be the preferred mode choice.

To estimate the actual average work-trip length in Perth a *weighted mean* analysis has been undertaken. It is noted that as the frequency of the number of trips per different trip length differ, a simple arithmetic average (where all the data is totalled and divided by the total summation) will not provide an accurate result and does not have a scientific meaning.

$$\overline{X} = \frac{\sum_{i=1}^{n} dij*Fij}{\sum_{i=1}^{n} Fij} \tag{5.1}$$

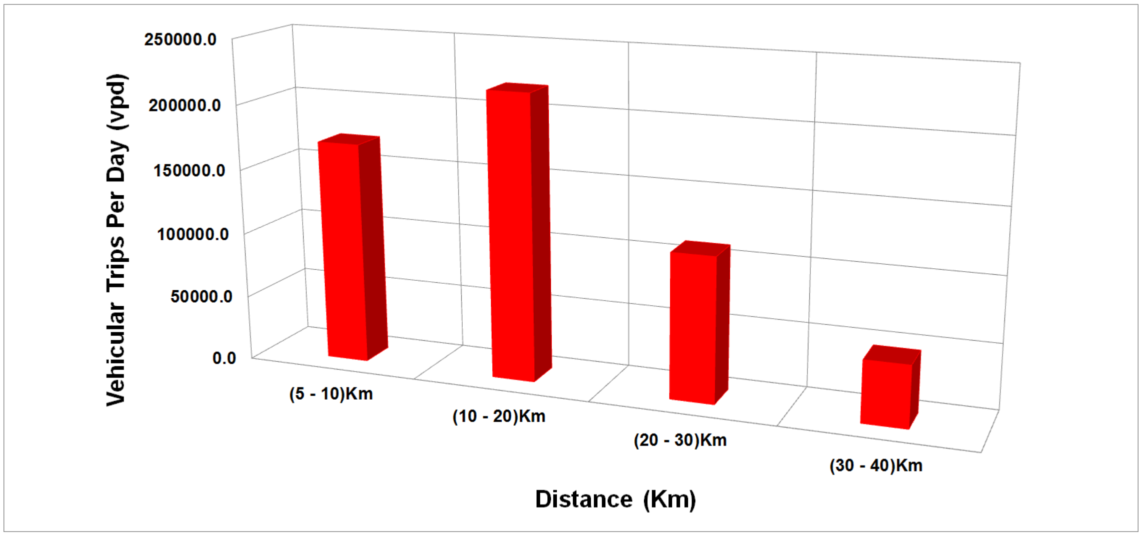
Therefore, the weighted mean of the work trips in this assessment is estimated to be 15.4 km. This means that most of the home-based vehicular work trips occur within a distance of 15.4 km.

To better estimate the most preferred distance of home-based work trips in Perth, the actual work trip data is also plotted in a bar chart format with 10 km increments, as illustrated in Figure 5.2.

According to Figure 5.2, most of the home-based work trips occur between 10 and 20 km distances (where the chart peaks). Therefore, it can be concluded that a distance of about 10 to 20 km is an acceptable distance for work commuters to find accommodation, and they seem to be satisfied to use their cars for commuting to work.

The outcomes of this study are considered valuable and can be used as a basis for a number of demographic analyses for Perth residents.

Figure 5.2: Actual work-trip volumes per day versus distance of travel – in 10 km increments



5.3 Curve-Fitting and Deterrence-Function Estimation

The actual trip length information provided by the DoPLH was then assessed to establish the constant parameters in the deterrence functions, using Equations 2 to 4 as set out in Chapter 2 and reiterated here:

$$Fij = a * e^{-\mathrm{b}(c\mathrm{ij})} \tag{5.2}$$

$$Fij = a * cij^{-b} \tag{5.3}$$

$$Fij = a * cij^{b} * e^{-(\mathrm{cij})} \tag{5.4}$$

The above equations were used to find the best curve-fitting match for the actual work trip-length data. It is noted that cij (generalised cost factor) in this assessment is only reflective of the distance of travel, as the only detailed information provided for the work trips was for distance of travel, which is considered the main impediment for travel. Therefore, **cij=dij** and is referred to as dij hereafter.

As the process of regressions using Gamma, Exponential and Power functions is a complicated one, and Microsoft Excel software cannot accurately assess the information, the actual trip-length data was imported into SPSS software for regression assessment.

SPSS is mathematical software which is widely used for statistical assessments. Curtin University conducts SPSS courses on a regular basis and has provided the software for this research. It is noted that there are many other tools and programs which can assist with the curve fitting analysis but access to the SPSS and Curtin's regular courses have suggested the author to use this software. The non-linear regression process in SPSS works in an iterative practice where a pair of dependent and non-dependent data is defined (where in this instance Fij is the dependent and dij is the independent data). For each of the three equations, a set of constant parameters is also introduced to the software with an initial number for each parameter so that the software commences the regression process. The regression process continues to a point when the best-matching fit is achieved. The software then reports the final parameters based on the last iteration. Assumption of the initial parameters in SPSS have been undertaken based on other similar studies in other literatures, the manual, the author's pas experiences with this software and particularly the values of the data which are under investigation.

5.3.1 Exponential Function Curve-fitting

The actual work-trip data in the form of Fij= number of work trips and dij= distance of travel was inserted into the SPSS software, and an Exponential function using Equation 5.2 was used to fit the data with an initial parameter of a=5000 and b=1. After a number of iterations, the best-fitting match to the data was achieved and parameters a and b were estimated to be *27693.462 and 0.04* respectively. A snapshot of the result of the Exponential regression is provided in Table 5.10.

Table 5.10: Results of the Exponential regression model – obtained from SPSS

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
a	27693.462	1887.264	23962.005	31424.919
b	.040	.004	.033	.047

Accordingly, the Exponential function which can best fit the actual work-trip data is as follows:

$$Fij = 27693.462 * \ e^{-0.04(dij)} \tag{5.5}$$

The Fij(s) estimated from this equation will result in a theoretical trip-length calculation for the Perth metropolitan area using an Exponential function. Therefore, the distances of travel were given to the Exponential function outlined in Equation 5.5, in order to test and compare the estimated theoretical trip lengths with the actual trip-length data provided by the DoPLH as discussed in section 5.2. The results of the theoretical trip lengths calculated via the Exponential function is detailed in Tables 5.13 to 5.16, along with the results of the Power and Gamma functions.

5.3.2 Power Function Curve-fitting

The actual work-trip data in the form of Fij= number of work trips and dij= distance of travel was inserted into the SPSS software and a Power function using Equation 5.3 was used to fit the data with an initial parameter of a=5000 and b=1. After a number of iterations, the best-fitting match to the data was achieved and parameters a and b were estimated to be 42262.618 and 0.572 respectively. A snapshot of the result of the Power regression is provided in Table 5.11

Table 5.11: Results of the Power regression model – obtained from SPSS

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
a	42262.618	7499.209	27435.349	57089.886
b	.572	.064	.445	.698

Accordingly, the Power function which can best fit the actual work trip data is as follows:

$$Fij = 42262.618 * (dij)^{-0.572} \tag{5.6}$$

The Fij(s) estimated from this equation will result in a theoretical trip-length calculation for the Perth metropolitan area using the Power function. Therefore, the distances of travel were given to the Power function outlined in Equation 5.6, in order to test and compare the estimated theoretical trip lengths with the actual trip-length data provided by the DoPLH as discussed in section 5.2. The results of the theoretical trip lengths calculated via Power function are detailed in Tables 5.13 to 5.16, along with the results of the Exponential and Gamma functions.

5.3.3 Gamma Function Curve-fitting

The actual work-trip data in the form of Fij= number of work trips and dij= distance of travel was inserted into the SPSS software, and a Gamma function using Equation 5.4 was used to fit the data with an initial parameter of a=5000, b=0.1 and c=0.01. After a number of iterations, the best-fitting match to the data was achieved and parameter a, b and c were estimated to *2742.519, 1.678 and 0.160* respectively. A snapshot of the result of the Gamma regression is provided in Table 5.12.

Table 5.12: Results of the Gamma regression model – obtained from SPSS

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
a	2742.519	496.284	1761.216	3723.823
b	1.678	.117	1.446	1.909
c	.160	.009	.142	.178

Accordingly, the Gamma function which can best fit the actual work trip data is as follows:

$$Fij = 2742.519 * (dij)^{1.678} * e^{-0.160} \qquad (5.7)$$

The Fij(s) estimated from this equation will result in a theoretical trip-length calculation for the Perth metropolitan area using Gamma function. Therefore, the distances of travel were given to the Gamma function outlined in Equation 5.7, in order to test and compare the estimated theoretical trip length with the actual trip-length data provided by the DoPLH as discussed in section 5.2. The results of the theoretical trip lengths calculated via the Gamma function are detailed in Tables 5.13 to 5.16, along with the results of the Exponential and Power functions.

Table 5.13: Actual and theoretical trip lengths (from 2-10 km)

dij	2	3	4	5	6	7	8	9	10
Fij (GAMMA)	6372	10723	14807	18348	21231	23432	24983	25941	26380
Fij (Exponential)	25564	24562	23599	22673	21784	20930	20110	19321	18563
Fij (Power)	28429	22545	19124	16832	15165	13885	12864	12026	11323

Table 5.14: Actual and theoretical trip lengths (from 11-20 km)

dij	11	12	13	14	15	16	17	18	19	20
Fij (GAMMA)	26378	26012	25352	24464	23406	22226	20968	19667	18350	17043
Fij (Exponential)	17836	17136	16464	15819	15198	14603	14030	13480	12951	12443
Fij (Power)	10722	10202	9745	9341	8979	8654	8359	8090	7843	7617

Table 5.15: Actual and theoretical trip lengths (from 21-30 km)

dij	21	22	23	24	25	26	27	28	29	30
Fij (GAMMA)	15762	14522	13333	12203	11136	10135	9201	8334	7532	6794
Fij (Exponential)	11956	11487	11036	10604	10188	9788	9405	9036	8682	8341
Fij (Power)	7407	7213	7032	6862	6704	6555	6415	6283	6158	6040

Table 5.16: Actual and theoretical trip lengths (from 31-40 km)

dij	31	32	33	34	35	36	37	38	39	40
Fij (GAMMA)	6117	5498	4933	4420	3954	3533	3152	2809	2500	2223
Fij (Exponential)	8014	7700	7398	7108	6829	6561	6304	6057	5819	5591
Fij (Power)	5928	5821	5720	5623	5530	5442	5357	5276	5198	5124

In Tables 5.13 to 5.16:

- the first row of the table shows the distance of travel
- the second row of the table shows the actual number of daily vehicle trips
- the third row of the table shows the estimated number of daily vehicle trips according to the established Exponential function
- the fourth row of the table shows the estimated number of daily vehicle trips according to the established Power function
- the fifth row of the table shows the estimated number of daily vehicle trips according to the established Gamma function.

5.4 Deterrence-Function Estimation

The results of the theoretical work-vehicle trip calculation were plotted against the distances of travel, as follows:

- Figure 5.3 shows the results of the theoretical assessments based on the Exponential function outlined in Equation 5.5
- Figure 5.4 shows the results of the theoretical assessments based on the Power function outlined in Equation 5.6
- Figure 5.5 shows the results of the theoretical assessments based on the Gamma function outlined in Equation 5.7.

Figure 5.3: Estimated theoretical work-vehicle trips – Exponential model

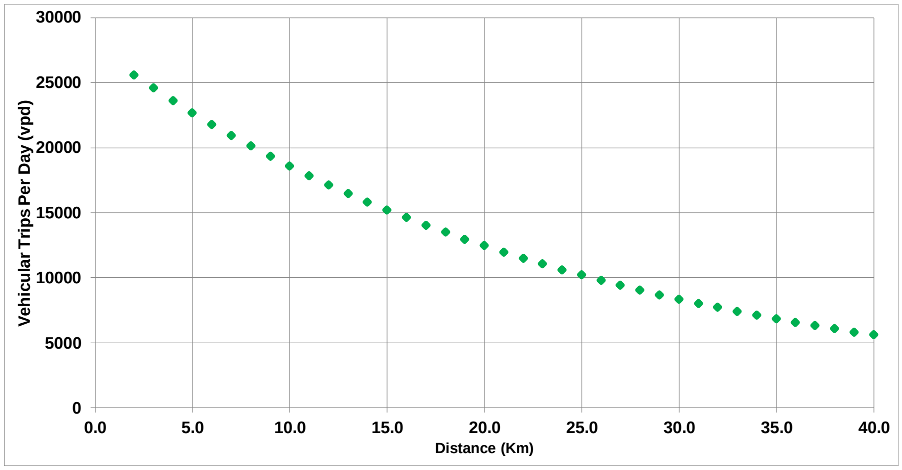


Figure 5.4: Estimated theoretical work-vehicle trips – Power model

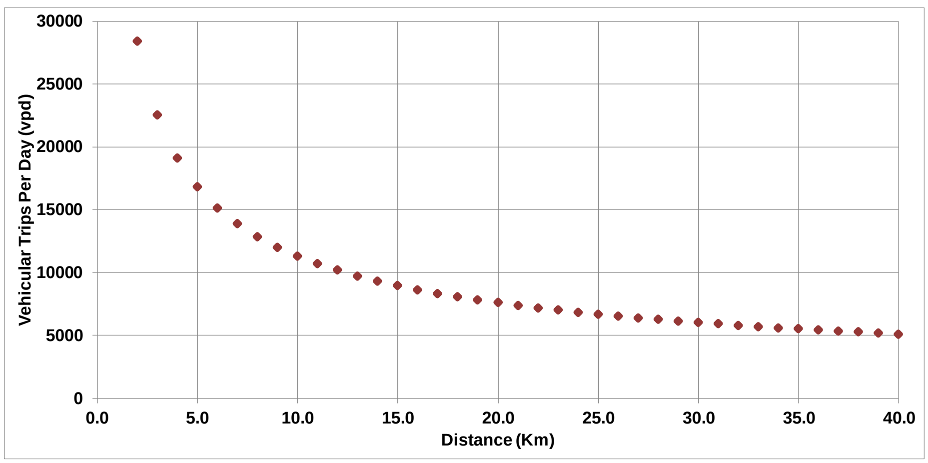
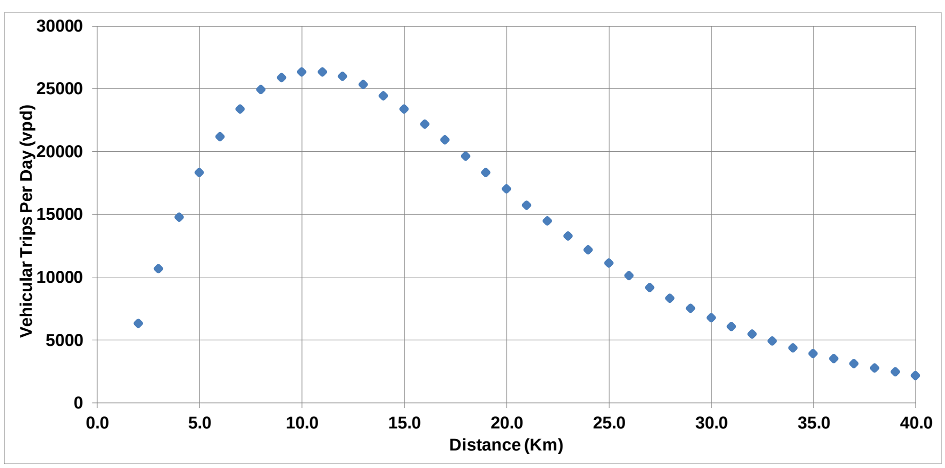
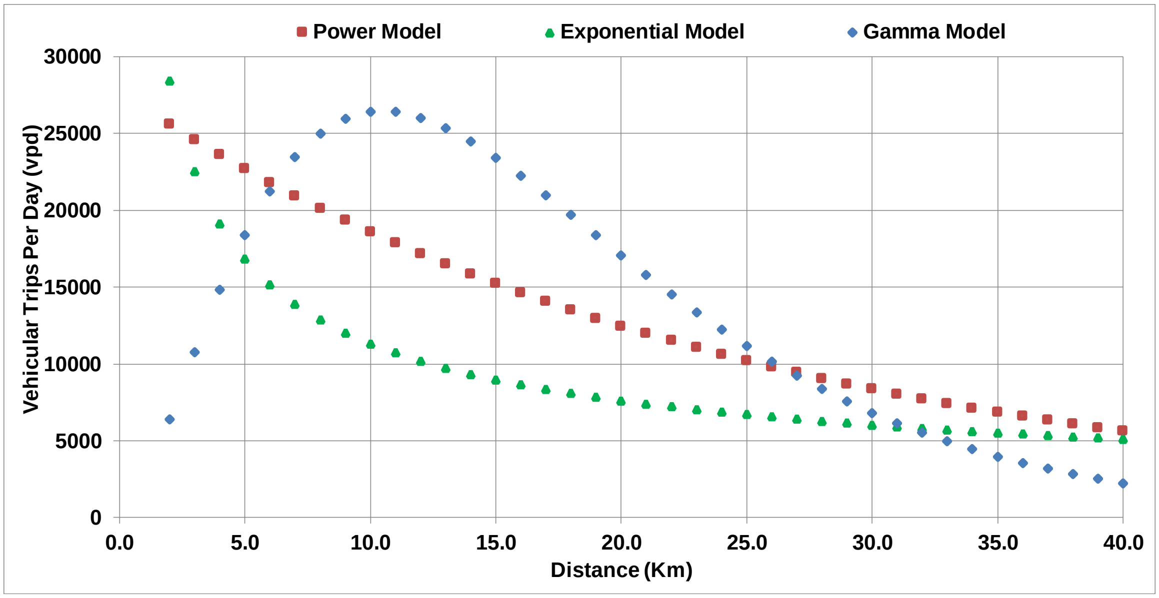


Figure 5.5: Estimated theoretical work-vehicle trips – Gamma model



In order to better compare the results of the three different methods, the resultant curves shown in Figures 5.3 to 5.5 are combined in a consolidated plot which is shown in Figure 5.6.

Figure 5.6: Combined estimated theoretical work-vehicle trips



As shown in Figure 5.6, the Gamma model shows the most accurate and most relevant curve when comparing it with the outcomes of the assessments of the actual work trip data shown in Figure 5.1.

The accuracy of the theoretical work-vehicle trip assessments is also tested against the actual work-vehicle trips by plotting the results of the Fij(s) for each model against the actual data provided by the DoPLH. It is anticipated that the results of the plots should follow a linear trend, of which the best-fitting model will have the highest R^2 of its respective trend line. Figures 5.7 to 5.9 show the result of the assessments.

Figure 5.7: Estimated and actual work-vehicle trips – Exponential model

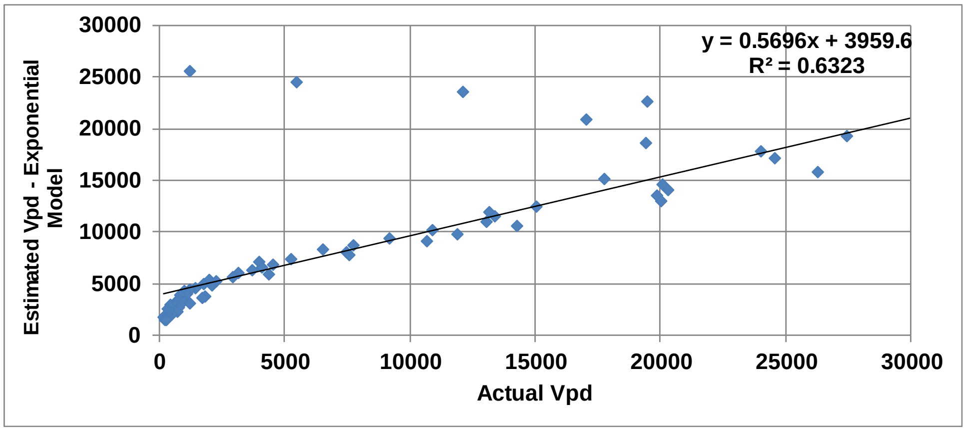


Figure 5.8: Estimated and actual work vehicle trips – Power model

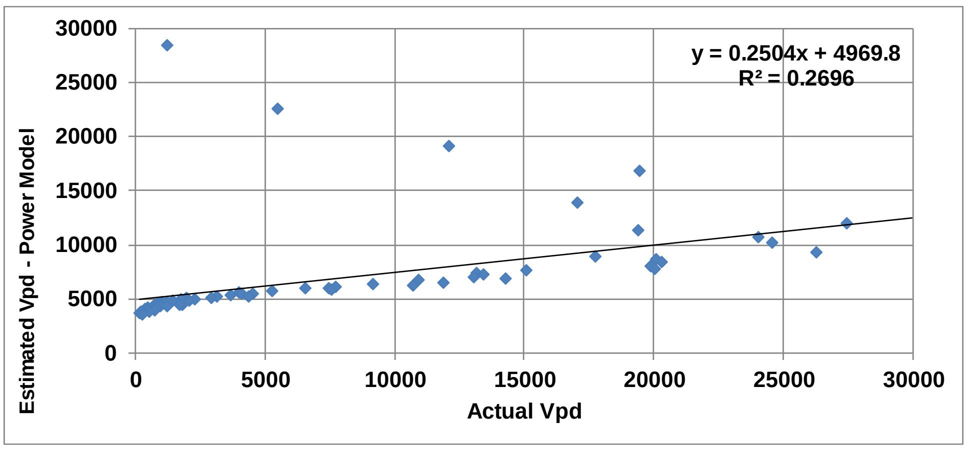
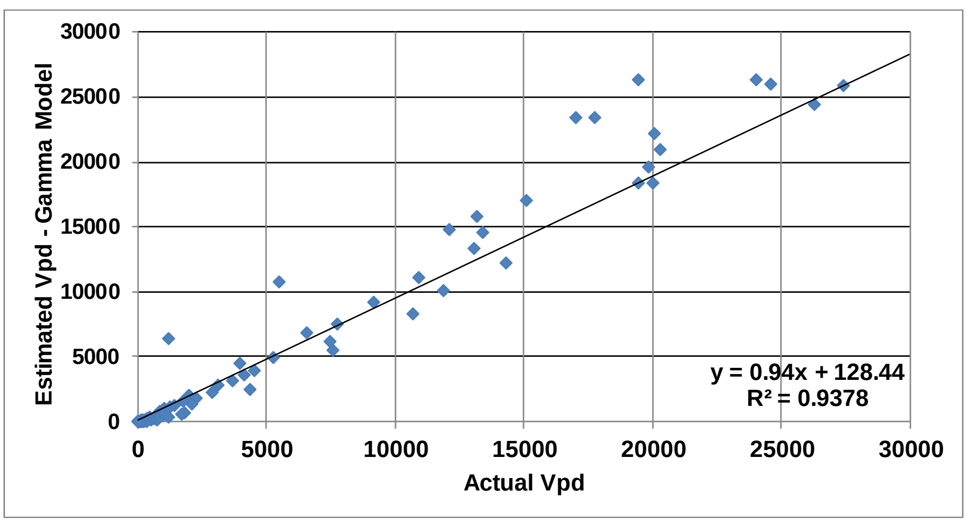


Figure 5.9: Estimated and actual work-vehicle trips – Gamma model



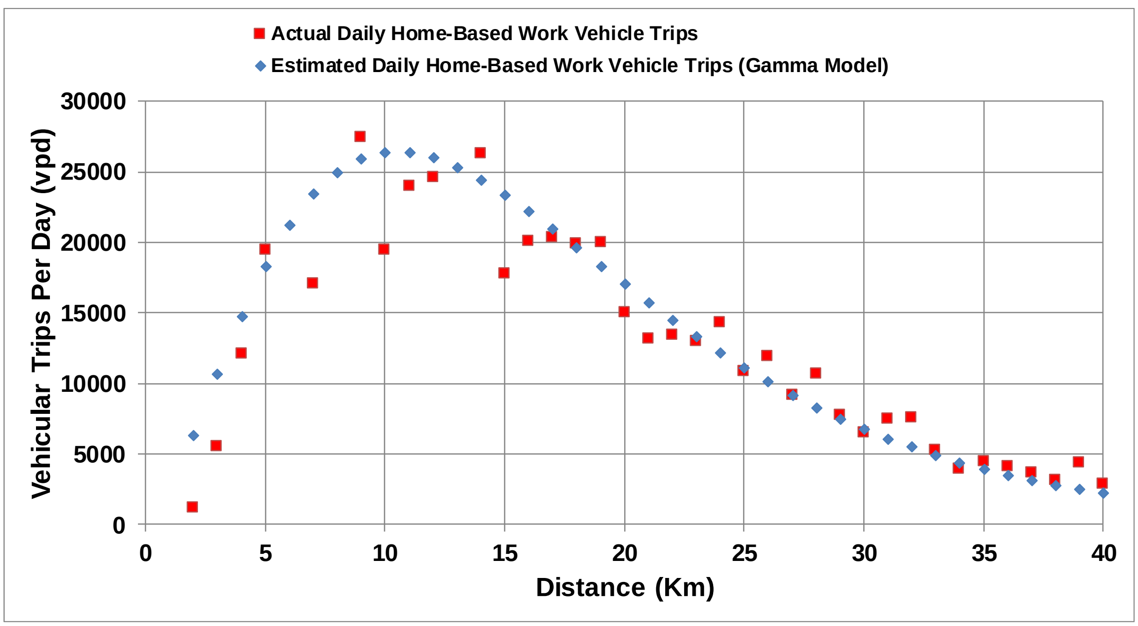
It is evident from the above plots that the Gamma function has resulted in the best-estimated model for the daily work trips, as the results of the theoretical work trips are quite similar to the actual work-trip data. The plot shown in Figure 5.9 follows a linear trend line with a reasonably high R^2 of about 0.938.

Accordingly, it is concluded that the Gamma function results in the best-fitting match among all three models and should be used as the deterrence function for the work trips in the Perth metropolitan area.

The results of the actual and theoretical work-vehicle trips are also shown in a consolidated plot in Figure 5.10, which confirms the accuracy and suitability of the established Gamma function for work trips.

Accordingly, it is concluded that the estimated Gamma function in this chapter should be used as the basis of the work-trip distribution in the Gravity Model.

Figure 5.10: Actual work trips versus theoretical work trips (Gamma model)



5.5 Summary

Detailed analysis undertaken on the actual work-trip information provided by the DoPLH was documented in this chapter. Three different curve-fitting models were employed to determine the theoretical vehicle work trips to find the best-fitting match. According to the outcome of the analysis on the actual trip-length data presented in this chapter, it has been concluded that the proposed Gamma function established as part of the current research can best fit actual work trips in the Perth metropolitan area and should be introduced into the Gravity Model for trip distribution.

6 STRATEGIC TRANSPORT MODELLING

To investigate the performance of the established Gamma deterrence function, a transport model for the entire Perth metropolitan area and Peel region was developed. The established deterrence function as discussed in Chapter 5 was used for the Gravity Model for distributing work trips. The accuracy and suitability of the work trip distribution was then assessed through a number of analyses and comparisons between the actual work-trip information provided by the DoPLH and the outcomes of the transportation model.

EMME 4 software has been used for developing the transportation model in this research. EMME software is a modelling tool which is widely used in the traffic and transportation industry to develop travel-demand models at strategic levels.

According to the software providers, EMME is used in almost half of the world's largest cities as a reliable traffic forecast tool. EMME can model different highways, freeways, roads, interchanges and intersections under different circumstances.

The EMME model includes a series of nodes, links and centroids. Nodes are representatives of intersections and junctions, links are representatives of roads and centroids are considered as the origin and destination (OD) traffic zones.

Usage of EMME model is for strategic modelling is ubiquitous around the world and accessibility to this software has suggested the author to use this software.

6.1 Network Coding

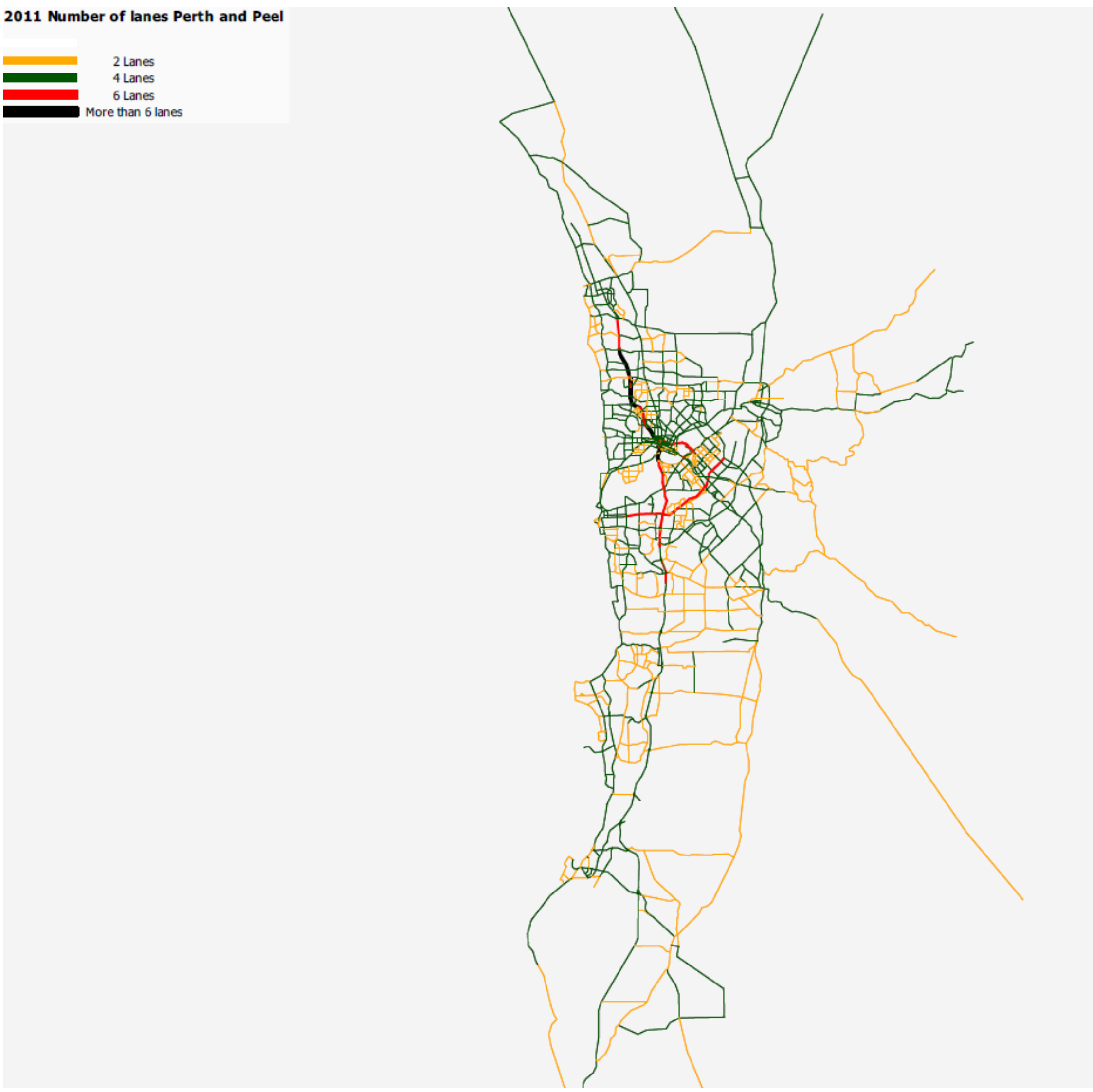
EMME 4 has the ability to incorporate satellite images from different geographical websites. To undertake the network coding for the Perth metropolitan area and Peel region, the latest aerial images from OpenStreetMap was used. The modelling area's spatial reference is set to UTM zone 50S.

Through liaison with Main Roads Western Australia (MRWA) a shapefile of the major roads within the Perth metropolitan area and Peel region was obtained, which included important features of each road, such as the number of lanes and speed limits. This shapefile was used for the network coding.

Firstly, the shapefile was inserted into the EMME model, and then all the major connections to the major roads were coded (nodes of the network) as the intersections, interchanges and junctions. Following this process, a network of links was developed between the nodes.

Figure 6.1 shows the extent of the modelling area and system of road networks coded for the study area, with the number of lanes shown in different colours.

Figure 6.1: Network coding – number of lanes



Once the network coding was concluded, the next step was to add the centroids to act as the traffic zones (ODs). The centroids for the study was representative of the SA2 zones. Accordingly, each SA2 zone (from 51024 to 51193) from ABS data for household survey 2011 was selected and a traffic production zone was assigned to it. The traffic production zone contains the total number of dwellings within each SA2 zone. For consistency, each production zone was given an identical label as its respective SA2 zone number (from 51024 to 51193). Furthermore, each SA2 zone was also given a non-residential zone to act as the attraction zone within the modelling area. Again, for consistency in labelling the non-residential zones, consideration was given to the SA2 labels. As such, each SA2 non-residential zone was given a number starting from 100024 and terminating at 100193. For example, the SA2 zone number 51054 was given a non-residential zone number of 100054.

The Perth area can be divided into two major sections, which is to the north and south of the Swan River. Therefore, the extent of the modelling area including the network coding and centroid locations is also divided based on north and south of the river and shown in five sections as per Figures 6.2 to 6.6.

Figure 6.2: Traffic zones to the north of Swan River

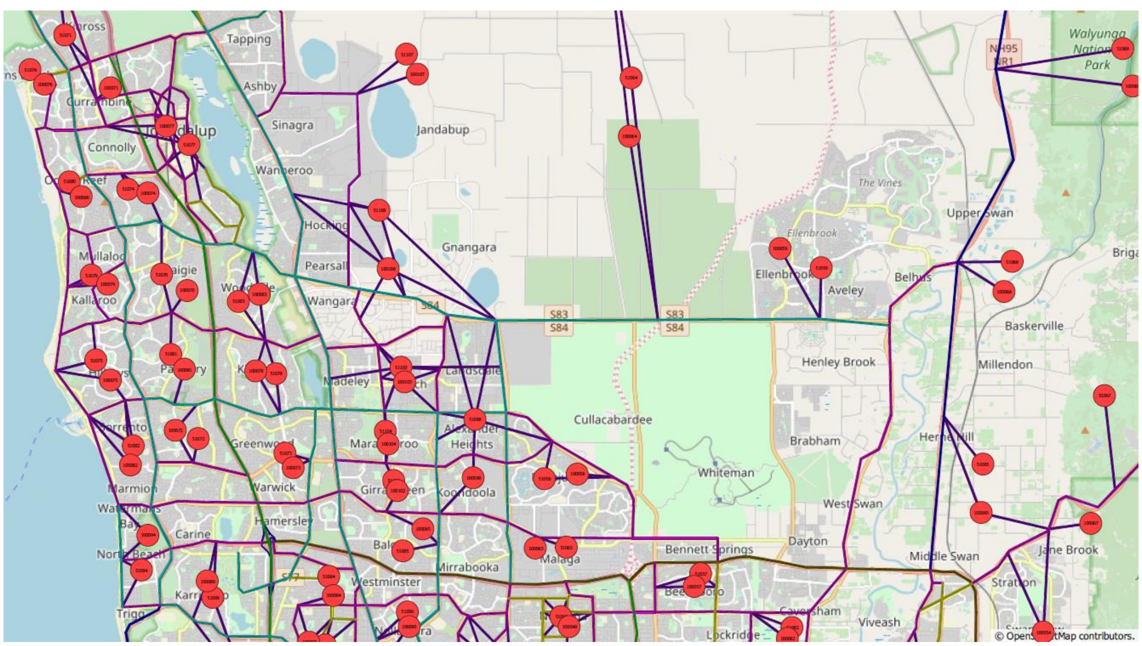


Figure 6.3: Traffic zones in Perth central area including Perth CBD

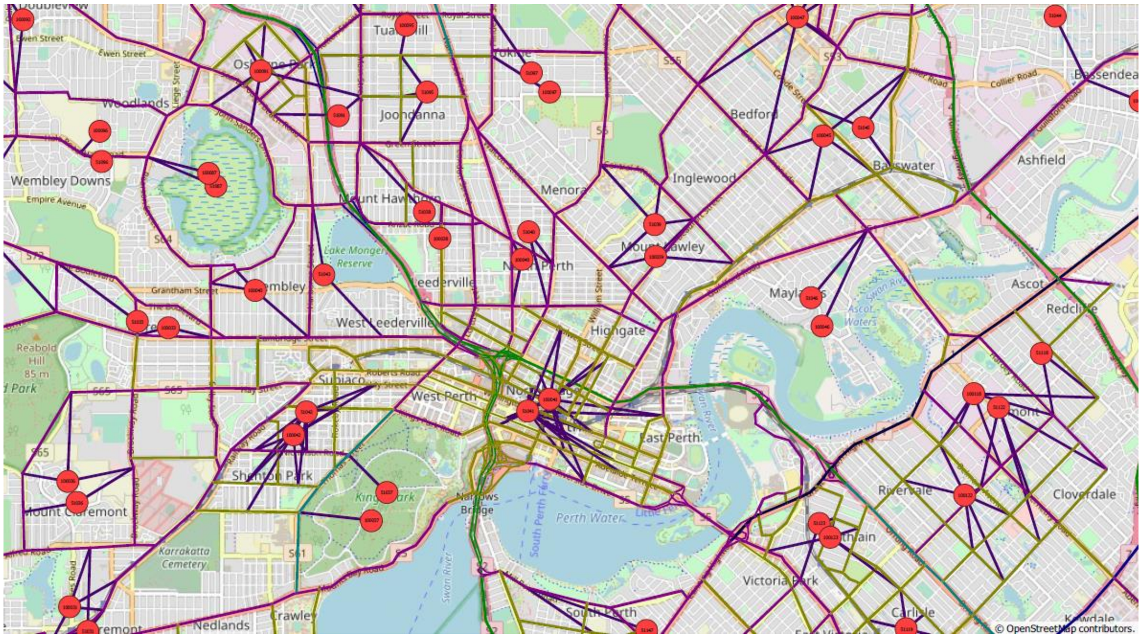


Figure 6.4: Traffic zones to the south of Swan River

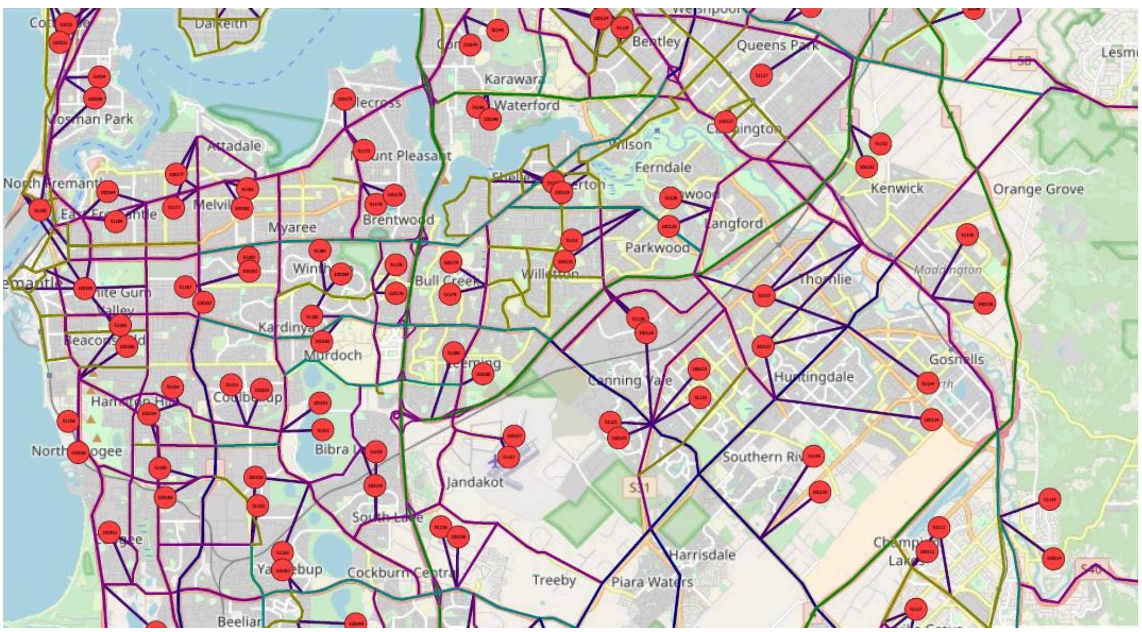


Figure 6.5: Traffic zones in the southern suburbs in Perth metropolitan area

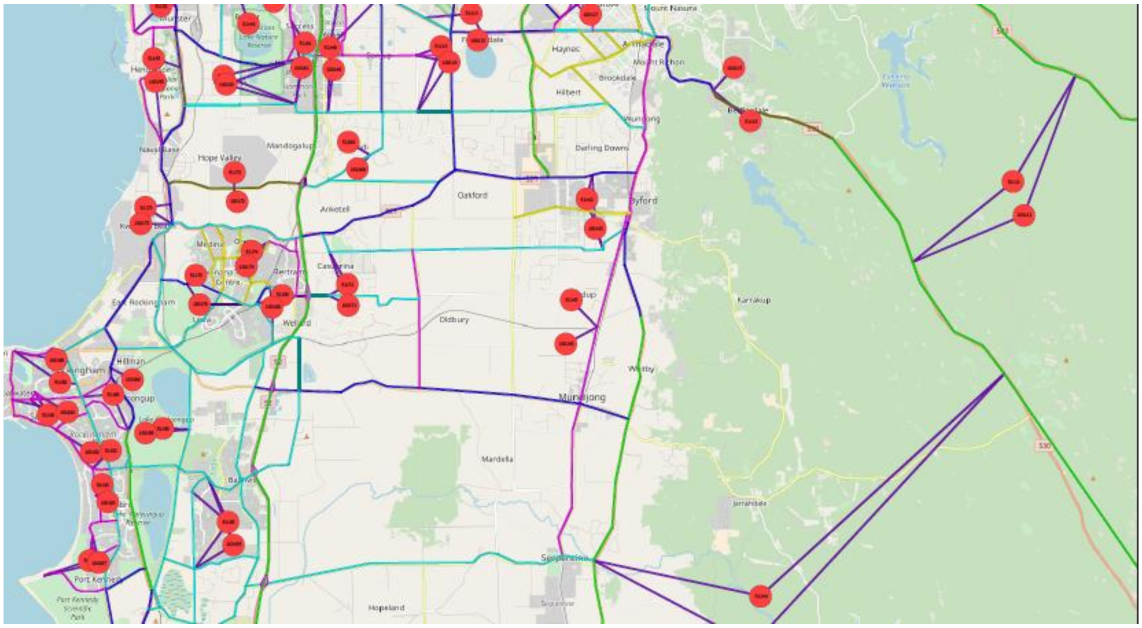
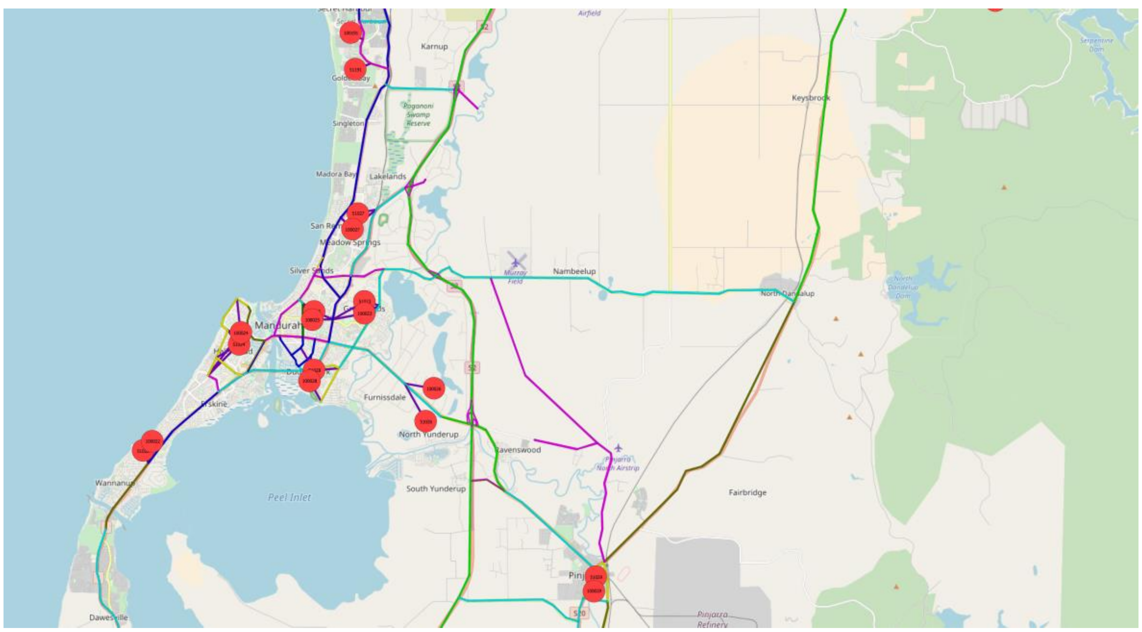


Figure 6.6: Traffic zones in Mandurah and Peel region



In all the above figures, the purple links which connect the traffic zones to the road network are known as zone connectors. Zone connectors can be considered hypothetical links that distribute the outgoing (produced) traffic from each production zone onto the road network or attract all the incoming (attracted traffic onto the attraction zones).

Overall, as part of the network coding, the following number of nodes, links and centroids were used to develop the transport model:

- 1,812 nodes
- 2,648 links both direction (5297 one direction)
- 354 centroids.

It is noted that eight centroids out of the total 354 centroids were assigned for external zones (zones at the boundaries of the modelling areas).

6.2 Application of Four-Step Modelling

The current EMME transport model has been developed in consideration of Four-Step Modelling (FSM). A detailed description of FSM was provided in chapters 2 and 3, and in this chapter the application of FSM will be discussed for the Perth transport model. The EMME model has been developed for an average weekday basis (full 24 hours).

Trip-Generation Step

The purpose of the trip-generation stage is to produce 24-hour trip productions and attractions for input into the trip-distribution stage. The land-use information discussed in Chapter 4 was used to estimate the trip generation of each traffic zone in the transport model.

Accordingly, and for the purpose of presenting different arguments, the trips were divided into four major categories based on trip purposes:

1. Home-based work trips.
2. Home-based education trips.
3. Home-based shopping trips.
4. Non-Home-based (NHB) trips.

The DoPLH conducts surveys to establish the travel survey data within Perth and its regions. This data is collected regularly (every five years) and known as the Perth and

Regions Travel Surveys (PARTS) data. Through the liaison process with the DoPLH, the latest available PARTS data for the year 2006 was obtained in order to review and respectfully use some of the relevant information for establishing the transportation model.

The PARTS data provided to the author measured different aspects of day-to-day travel patterns including origin, destinations and purpose of travel. According to the *Perth and Regions Travel Survey Final Report*, the data collection covered every day throughout the survey period (20 October 2002 to 30 September 2006), and the number of responses was 16% above that required in the project scope (Data Analysis Pty Ltd 2006). The methodology used to establish the PARTS data was to undertake an ongoing survey on a number of randomly selected sample spreads within the area of study. PARTS is a self-completion survey where all the sampled households are contacted and asked to record travel patterns of the residents and any overnight visitors throughout a 24-hour period. The households under investigation are randomly selected in each suburb. According to the outcome of the PARTS data collected for the years between 2003 and 2006, a total of 10,947 results were returned, which met and exceeded the initial specification of the project proponents by about 16%. At the time of conducting this research, the latest available PARTS data was requested from the DoPLH in June 2015. A detailed review of the PARTS data has been undertaken as part of this research. As part of the process review of the data, the percentages of different trip purposes were extracted from within the Perth metropolitan area and its regions, and are summarised in Table 6.1.

Table 6.1: Percentages of different trip purposes

Home-based work	16.1%
Home-based education	6.8%
Home-based shopping	17.7%
Home-based social–recreational	15.1%
Home-based chauffeuring	9.8%
Home-based other	7.4%
Non-home-based	27.1%

Source: (Data Analysis Pty Ltd 2006)

As demonstrated in Table 6.1, a total of 72.9% of all trips within Perth and other regions is estimated to be home-based trips (trips originating from homes and by the resident commuters). The remainder of the trips (27.1%) are estimated to have origins rather than homes and these are the NHB trips. These trips can be different in nature such as work-based trips, which means trips originating from workplaces.

The *RTA Guide to Traffic Generating Developments* (Roads and Maritime Services (NSW) 2002) (referred to in Chapter 2) provides a range of daily and peak-hour trip generation rates for different land uses based on actual surveys undertaken in Australia and mainly in the eastern states (especially in Sydney). The residential trip rate used for the trip-generation step was based on the daily rates provided in the *RTA Guide*, as shown in Table 6.2.

Table 6.2 suggests and specifies the trip rates of nine vehicles per day/dwelling of houses, four to five vehicles per day/dwelling of high to medium-density residential flat building and five to 6.5 vehicles per day/dwelling of high-density residential flat building. For a simple trip-generation assessment, and as the developed model does not allow for any mode other than cars, a unique trip-generation rate was attempted for the entire modelling area without going into too much detail, which would otherwise fall outside the scope of this work. It is again noted that the transportation model has been developed primarily to investigate the performance of the established deterrence function supplemented into the Gravity Model for distributing work trips.

Table 6.2: Trip rates specified for residential dwellings

Land Use	Traffic generation rates	
	Daily Vehicle Trips	Peak Hour Vehicle Trips
Residential		
Dwelling houses	9.0 / dwelling	0.85 per dwelling
hMedium density residential flat building	*Up to 2 bedrooms*	
	4-5 / dwelling	0.4-0.5 / dwelling
	3 bedrooms or more	
	5-6.5 / dwelling	0.5-0.65 / dwelling

Source: Roads and Maritime Services (NSW) (2002)

Accordingly, a trip rate of 8vpd was used for the trip generation, which is within the specified range of trip rates suggested by the *RTA Guide*. It is also noted that the rates specified by the guide result in an arithmetic average of about 6.4vpd; however, the trip-generation rates are usually higher in Perth compared to the eastern states on multiple grounds, such as different availability/accessibility of public transport, people's actual intention for driving, number of cars per household and less traffic congestion during the peak periods. Therefore, it is expected that the trip rate of 8vpd would result in a more robust and conservative assessment. It is important to note that the main objective of the modelling is to investigate the suitability of the recommended Gamma function. Therefore, the usage of different trip rates is not anticipated to have significant impact on the assessments of the main scope of this thesis.

Accordingly, the trip generation for each production zone was estimated based on the assumed trip rate of eight and in accordance with the percentages provided in Table 6.1.

The trip-generation step had been undertaken in a Microsoft Excel spreadsheet. The output of the trip-generation step was then distributed between the production and attraction zones during the second step of FSM.

Trip-Distribution Step

Trip distribution can be considered an analytical process where two-dimensional matrices of trips are produced from one-dimensional production matrix and one-dimensional attraction matrix. Trip generation refers to the number of trips starting or ending at **residential land uses** and trip attraction refers to trips **starting or ending at other land uses** (retails, offices, showrooms, warehouses, industrial areas, schools, etc.). The trips within the modelling area have been distributed based on the Gamma function as discussed in Chapter 5.

It is noted that parameters a, b and c were precisely calibrated for the work trips, as the available and detailed travel survey data provided to the author was for work trips at the SA2 level only.

Consideration for calibrating the trip distribution for trip purposes other than work trips was given to the review of the results and outcomes of the PARTS data for those trip purposes. The Gamma functions used for shopping trips and education trips were not precisely calibrated in the same manner as was undertaken for work trips; however, it was attempted to have these parameters estimated such that the modelled trip length was as close as possible to the actual trip length information for these two trip purposes.

The scope of work as outlined in the Objectives section of this thesis only allows for the arguments and analyses to be made based on work trips, as the detailed information available to the author at the SA2 level was for work trips only.

Mode-Choice Step

As access to accurate and detailed information about the travel demand based on different modes of transport was difficult to obtain, and for the purpose of a simple modelling exercise, this step was not encountered and it is assumed that there is only one mode of transport available for commuters in the developed transportation model, which is cars. It is noted that the mode-choice step was taken into consideration by applying the trip-production rates for the trip-generation step.

Trip-Assignment Step

Assignment of the trips was based on the fixed-demand traffic assignment module in EMME 4 software.

Accordingly, the trips are assigned to the modelled road network in such a way that their total travel time is minimised. Travel time calculations for the road network take into consideration the road type, average speed and number of lanes along each route. The fixed-demand assignment is set to try to assign the traffic through 100 iterations in order to minimise the travel time.

All the major highways, freeways and most of the major roads within the Perth metropolitan area and Peel region plus some of the local distributor roads were coded in EMME to assist with the trip-assignment step. Some of the major freeways and highways coded in EMME are as follows:

1- Mitchell Freeway to Kwinana Freeway and further down to Old Coast Road in the Peel region

2- Tonkin Highway

3- Roe Highway

4- Reid Highway

5- Stirling Highway.

It was also attempted to code the Perth CBD area in finer and more detail, including the local roads, to try to replicate the city's traffic as accurately as possible.

Trip assignment procedures and commands in EMME 4 are as follows:

Note: the selected options are highlighted in red.

1- In EMME prompt module number 5.11 was run:

Select: Type of assignment

1= fixed demand traffic assignment

2= fixed demand transit assignment

3= variable demand traffic assignment

4= end.

2- Select: 1= more iterations on old assignment

2= new assignment

3- Select:

1= single class assignment on auto mode

2= single class assignment with generalized cost

3= multiclass assignment

4= multiclass assignment with generalized cost

5= generalized cost multiclass assignment with class specific volumes

6= generalized cost multiclass assignment with path analysis.

4- Select: Source for additional volumes

1= no additional volumes

2= auto equivalent of transit vehicles

3= user data on links and turns

4= transit vehicles and user data

5= assign additional demand (additional options assignment).

5- EMME would now need the inputted two-dimensional OD matrix which was established in the trip-distribution step to distribute the trips between production and attraction zones (mf12 in our study).

6- EMME is now ready to start the trip assignment and the following command will appear for the user to choose the intended assignment exercise:

5. A S S I G N M E N T   P R O C E D U R E S

5.11 Prepare for standard traffic or transit assignment

5.21 Standard traffic assignment

5.22 Standard traffic assignment (parallel)

5.23 SOLA traffic assignment

5.25 Path-based traffic assignment

5.31 Standard transit assignment

5.32 Extended transit assignment

5.33 Extended transit assignment (parallel)

5.34 Prepare access/egress nodes for individual transit trips

5.35 Analyze / assign individual transit trips

5.36 Deterministic transit assignment.

7- EMME starts the 100 iterations to try to assign the traffic with the aim of minimising the travel time and in consideration of the available road network. It is noted that the 100 iterations is optional and can be changed by the user.

The FSM is completed and all the produced traffic volumes from the generation zones have been distributed. The model has assigned them to the road network considering the only mode of transport. The output of the model is now the traffic volumes on each link. EMME provides a range of plots and outputs which have great value for undertaking a number of different analyses on the data. EMME reports the traffic volumes on each road link (in separate directions). To observe the outcomes, a plot of traffic volumes should be run in the software. The EMME traffic volumes are available as ***volau***.

It is now time to review and compare the modelled traffic volumes with the observed traffic volumes.

6.3 Model Calibration – Traffic-Volume Calibration

The calibration of the EMME model was based on the observed traffic volumes on the links obtained from the Main Roads WA website (2017) which provides historical traffic data on roads. The actual traffic volumes for the years 2010 to 2011 on a number of links were assigned, and a comparison between the actual observed traffic volumes and the modelled traffic volumes was undertaken. A total of 346 links were assigned with the observed traffic volumes to undertake traffic-volume calibration analysis. Links with the observed traffic volumes assigned were given an additional attribute labelled as @count. For example, when @count on a link is 1,500vpd it means the discussed link carries 1,500vpd in real life.

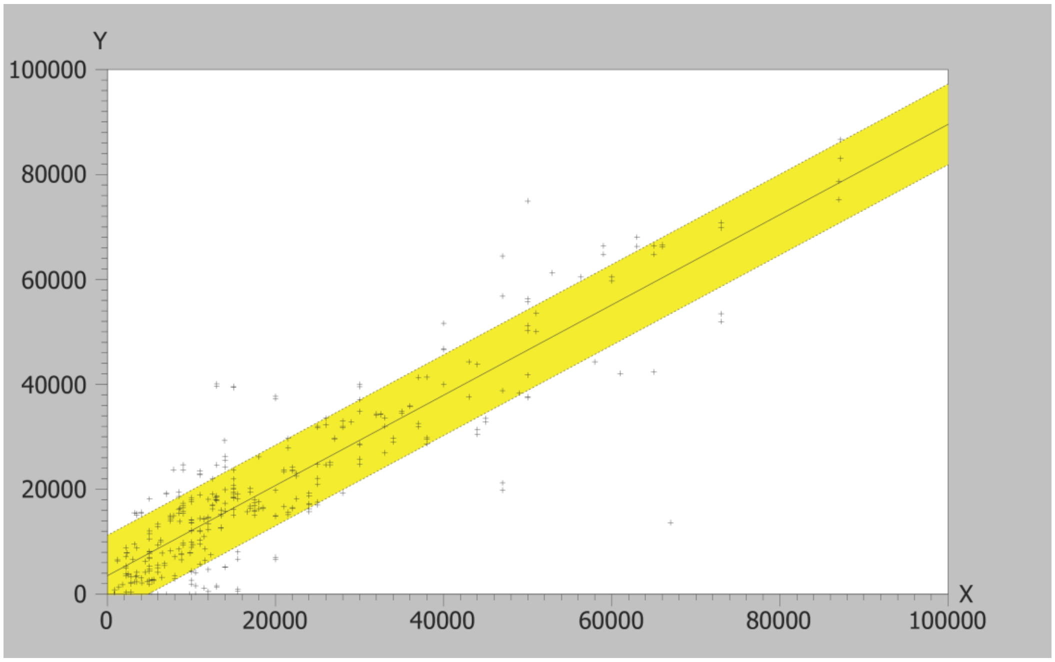
Note: The observed traffic volumes assigned to the links were for Average Weekday (AWD) traffic flow.

In order to assess the accuracy of the traffic-volume calibration, the results of the modelled traffic volumes were plotted against the actual traffic volumes on links (links with @count).

Figure 6.7 shows the EMME scatter plot which contains the result of the model-calibration assessment. The x-axis demonstrates the observed traffic volumes against the y-axis, which demonstrates the modelled traffic volumes on links.

The linear trend line shows the accuracy of the traffic-volume comparisons between those modelled and the actual traffic counts obtained from the MRWA website on 346 links. As can be seen in this figure, a great portion of the dot points follow the linear trend.

Figure 6.7: Link scatter plot for comparing traffic volumes

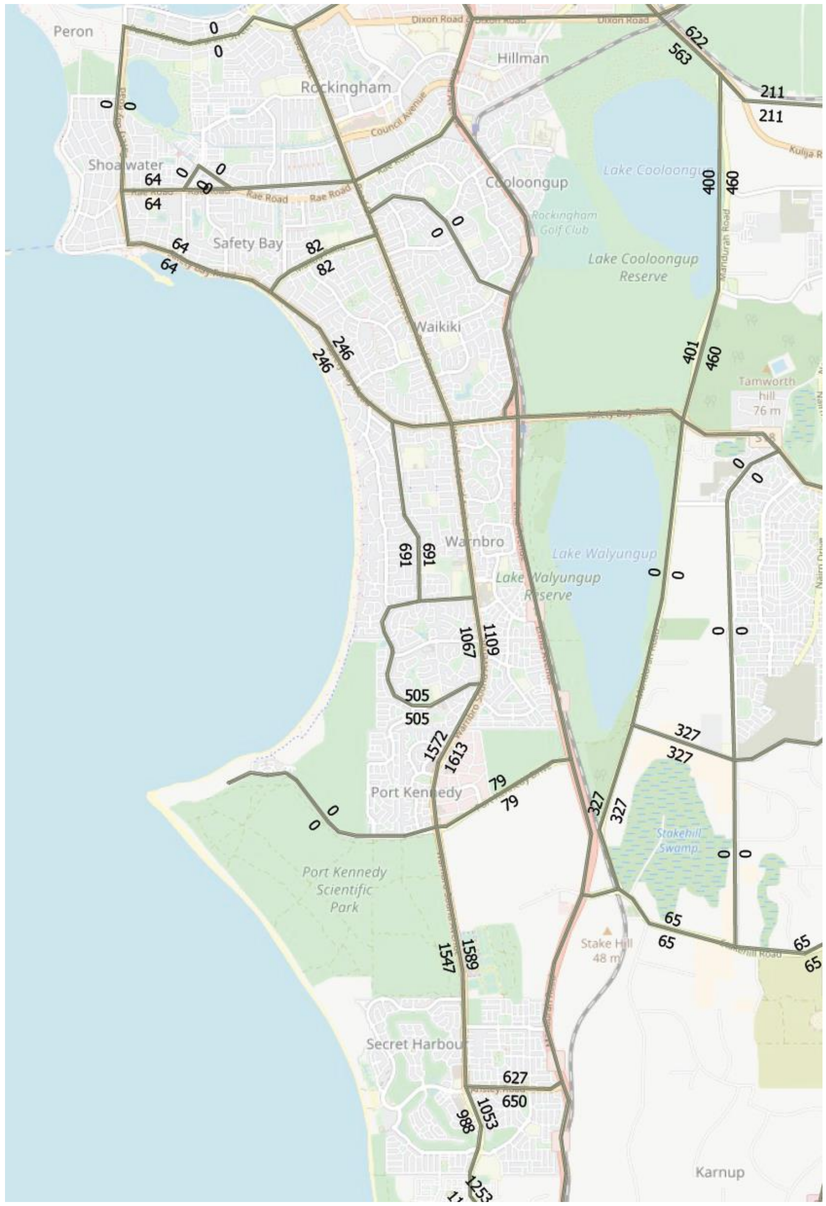


Source: EMME model

As a result of the analysis, the R^2 of the scatter plot (according to EMME) was established at 0.784, which shows the accuracy of the traffic-volume calibration. It is noted that calibrating the traffic volumes in such a large modelling area and with 346 links under assessment is a very difficult task, and the outcome of 0.783 for R^2 is considered a reasonable and accurate outcome.

A second method, just to obtain an idea of the traffic volume calibration, was to take a sampled area from the model and review the volau-@count volumes. The volau is the modelled traffic volumes and the @count is the actual traffic volumes. Obviously the closer the volau-@count to zero the better the traffic-volume calibration is deemed. Figure 6.8 shows the Rockingham area to the south of the Swan River. The numbers appearing in this figure demonstrate the accuracy of the model. As can be seen, in general the value for volau-@acount is in the order of less than 1,000vpd, which confirms a good traffic-volume calibration outcome for this area. It is noted that the zero values on some of the links in Figure 6.8 confirms that the modelled traffic volumes on these links are quite close to the actual traffic counts.

Figure 6.8: volau-@count for Rockingham area



Source: EMME model

It is noted that the focus of this thesis is to calibrate the trip distribution and not the traffic volumes; however, the outcome of the transportation model is also reviewed with respect to the traffic volumes as well as trip-distribution calibration to confirm the performance of the EMME model developed as part of this research.

The EMME model developed can be considered a tool for future travel-demand forecasting analysis. Now that the model's performance is generally acceptable, it is time to review the performance of the work-trip distribution in consideration of the established distance-deterrence function.

6.4 Summary

This chapter contained information about how the transportation model was developed in EMME software. A brief review of the road-network coding was presented and, importantly, the application of FSM was discussed in detail.

The trip-generation step was acknowledged to be in accordance with the trip rates provided in the *RTA Guide* and the percentages of trip purposes as outlined in PARTS data.

Trip distribution was acknowledged to be through the application of a developed Gravity Model, which was supplemented with the Gamma function established in Chapter 5.

The mode-choice step was acknowledged to be not encountered, as the transport model is not deemed to be multimodal and cars are the only mode of transport in the model.

Traffic assignment was acknowledged to be via a fixed demand in EMME. A review of the EMME commands to undertake the fixed-demand assignment was presented in this chapter. It was also established that the traffic volumes on links were attempted to be calibrated in consideration of the available actual traffic volumes for the year 2010 to 2011 for a total of 347 links.

The traffic-volume outputs from the EMME model were plotted against the actual observed traffic volumes to investigate the accuracy of the traffic-volume calibrations, and it was established that the modelled traffic volumes follow a linear trend line with the actual observed traffic volumes.

To demonstrate the accuracy of the traffic-volume calibration, a sample from the transportation model (for the Rockingham area) was reviewed and presented in this chapter.

7 MODEL OUTPUT AND ANALYSIS

The outcomes of the modelling will be discussed in this chapter. The main outcome of any strategic transportation model is the traffic numbers on links. The traffic numbers shown for a Base Year scenario should be read and considered with respect to the existing actual traffic counts on roads. As discussed in several areas throughout this thesis, the main purpose of the transportation modelling undertaken as part of this research was to assess the performance of the proposed Gamma function, and as such the focus of this chapter will be on the assessments of the modelled trip distribution and trip-lengths analysis. However, a brief overview of the daily traffic volumes obtained from the model will also be presented.

7.1 Daily Traffic Volumes

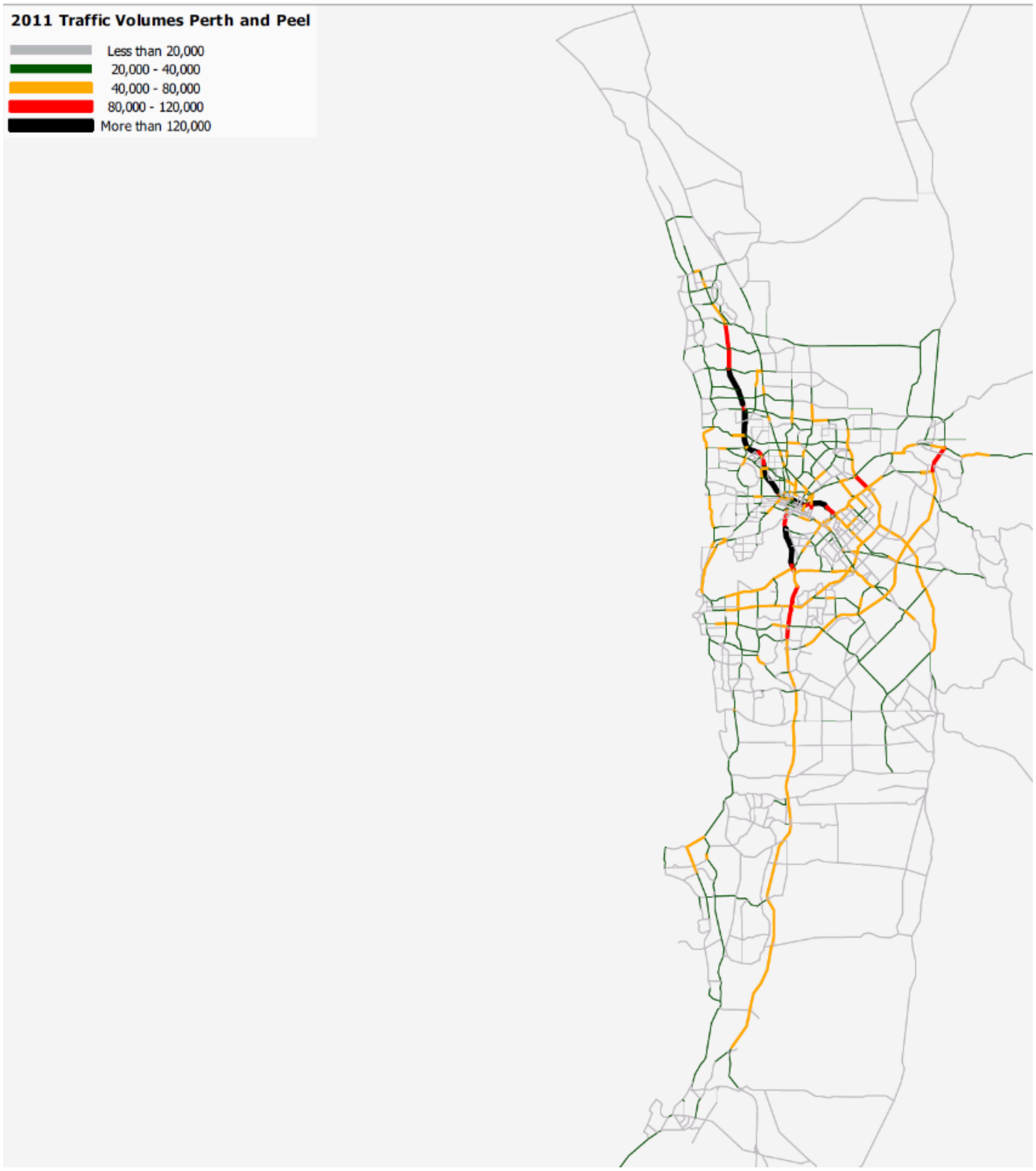
The modelled daily traffic volumes on the road network for the Base Year (Year 2011) are shown in Figure 7.1. It is noted that due to the extent of the modelling area, the output of the traffic volumes on each link could not be plotted in one consolidated map, and as such Figure 7.1 shows the daily traffic volumes in a color-coded manner, of which details of the colors are depicted in the legend.

The outcomes of the transportation model for the home-based work trips are reviewed, analysed and assessed, and detailed arguments and discussion on the outcomes of the assessments will be made in this and the following chapters.

It is anticipated that the home-based, work-trip distribution outputs from the model are calibrated with the home-based, work-trip length information provided by the DoPLH. This is because the Gamma function used for the Gravity Model to distribute the home-based work trips in the model showed a good curve-fitting match with the actual data.

Furthermore, the constant parameters of a, b and c in the Gamma function were derived from a mathematical programming software and followed a scientific approach.

Figure 7.1: Daily traffic volume



Accordingly, the performance of the distance-deterrence function established in Chapter 5 is now to be tested through the outcome of the EMME transportation model. If the output of the EMME model in terms of home-based, work-trip distribution is found to be in line with the observed trip-length data provided by the DoPLH, then it can be concluded that the Gamma function proposed in this research is performing properly and can be used for other modelling exercises for the Perth metropolitan area.

Several different comparison tests have been conducted to assess the performance of the Gamma deterrence function, which will be presented in detail.

7.2 Home-Based Work-Trips Analysis

EMME software allows for obtaining various plots to undertake different analyses on different work trips. Therefore, the Origin and Destination (OD) matrix for the work trips was run in the model and the model outcomes were extracted.

One of the valuable features of EMME software is the ability to extract different histograms to undertake different analyses on different attributes of links, nodes and zones.

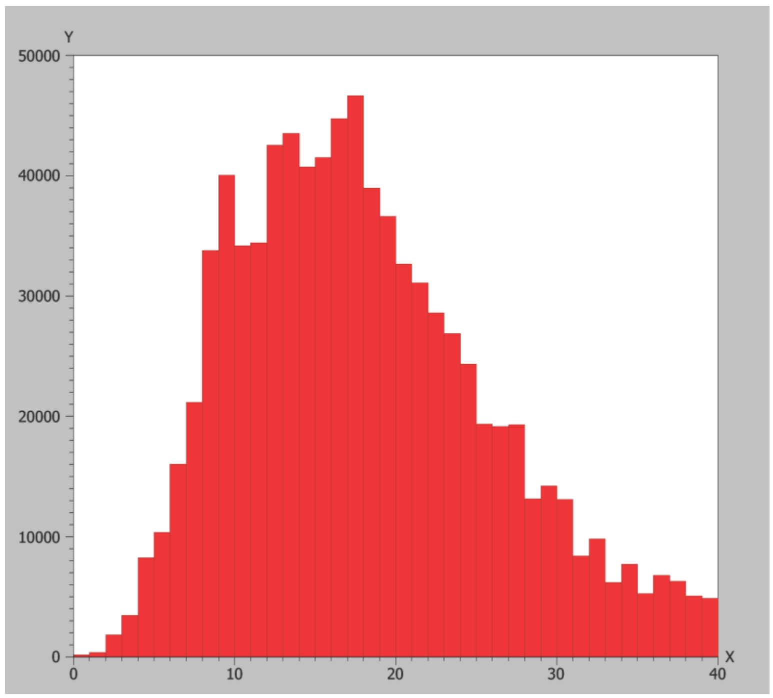
The EMME histograms can plot the results of the traffic volumes for each trip purpose separately and against their respective distance of travel.

As such, the home-based, work-traffic volumes are plotted against the distance of travel to provide an opportunity for comparing the same plot with the actual data. In Figure 7.2, the x-axis is the distance of travel and the y-axis is the modelled traffic volumes.

Figure 7.2 confirms that the modelled traffic volumes start increasing from 0 to 10 km when it exhibits its first peak at about 10 km. Figure 7.2 also clearly demonstrates that most of the work vehicular trips occur within the distance of 10 to 20 km, which is in line with the findings of the actual work-trip assessments derived from the DoPLH travel data.

As shown in Figure 7.2, the outcome of the EMME model is in agreement with the actual observed home-based work trips provided by the DoPLH. This similar match can be the first evidence for the home-based, work-trip distribution calibration. The calibration of the trip length based on the actual trip-length information provides modellers with a level of peace of mind that the model does not distribute the trips in an unrealistic manner. It is important to note that having a realistic distribution in transportation modelling is of great value and is a measure for modellers to assess the model. In Figure 7.2 the x-axis demonstrates the distance of travel in kilometer against the y-axis, which demonstrates the number of home-based work trips.

Figure 7.2: Home-based work-trips length



Source: EMME model

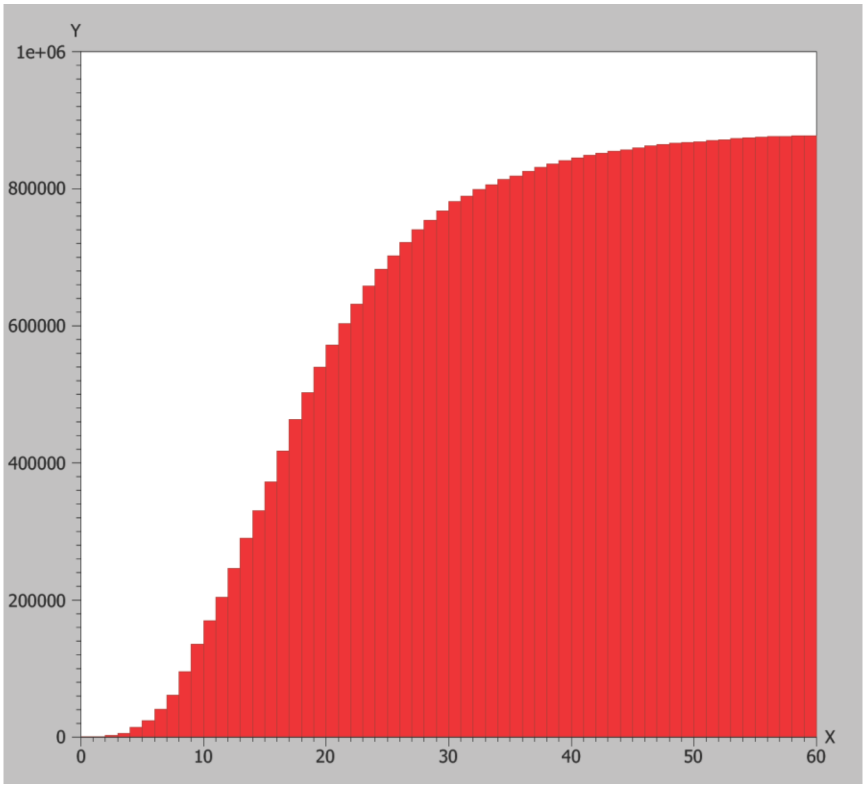
The modelled home-based work trips are also plotted in a cumulative manner, as shown in Figure 7.3.

In Figure 7.3 the x-axis shows the distance of travel in kilometer and the y-axis shows the total number of home-based work trips.

For example: at a distance of 4 km the total number of cumulative trips is calculated as Fij (at 1 km) + Fij (at 2 km) + Fij (at 3 km) + Fij (at 4 km).

Figure 7.3 shows that after a 35 km distance, the plot shows a tangent. This tangent can be interpreted as demonstrating that the number of home-based work trips decreased. In real life, it can be concluded that people prefer not to use private cars to commute to work, and other modes of transport (such as public transport) might be their preferred way to travel.

Figure 7.3: Cumulative home-based work-trips length



Source: EMME model

7.3 Home-Based Work Trips – OD Matrix Comparisons

In order to accurately assess the performance of the model in terms of the trip-distribution calibration for work trips, the OD matrix of work trips was extracted from the EMME model.

Accordingly, an excerpt of the OD work-trip matrix extracted from EMME is shown in Table 7.1. Table 7.1, shows the distances between each pair of zones in kilometer. As an example, the distance between the residential zone number 51080 to a non-residential zone number 100025 is estimated in the model to be about 0.07km. The OD matrix extracted from the EMME model is considered to be accurate as the zoning system undertaken in the

EMME model is in accordance to the latest available online aerial imageries provided in EMME. This is considered to be the best way to determine the distances between the zones.

Table 7.1: Home-based work trips – modelled OD Matrix (trips originated from zone 51080 to 51104 and attracted by the zones 100022 to 100035)

	100022	100023	100024	100025	100026	100027	100028	100029	100030	100031	100032	100033	100034	100035
51080	0.003655	0.027644	0.007488	0.070572	0.001247	0.01702	0.004562	0.003629	2.449189	19.85182	4.317028	6.566518	2.763153	34.63567
51081	0.005797	0.043268	0.011833	0.11043	0.001966	0.026455	0.007165	0.005757	2.862392	26.05309	5.160058	8.191918	3.326403	46.38101
51082	0.006396	0.047738	0.013056	0.121838	0.002169	0.029188	0.007905	0.006352	3.571223	32.66511	7.321135	9.037215	4.767633	51.16878
51083	0.005306	0.039666	0.010835	0.10124	0.001801	0.024273	0.006566	0.005269	2.704661	24.38741	4.356452	7.736732	2.826155	43.3823
51084	0.018512	0.135325	0.037572	0.345258	0.00622	0.081845	0.02253	0.018383	5.695793	60.30101	11.74835	16.56111	7.711616	109.847
51085	0.015257	0.112405	0.031032	0.286821	0.005145	0.068263	0.018677	0.015151	5.173625	54.02644	10.18081	15.77941	6.77106	101.2118
51086	0.032787	0.237854	0.066405	0.606759	0.010979	0.143274	0.039678	0.032557	7.615125	90.97452	18.20224	23.23575	12.24837	170.1901
51087	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51088	0.024328	0.176809	0.049297	0.451049	0.008153	0.106606	0.029481	0.024158	5.452297	80.39273	19.4235	18.73588	13.17757	131.5147
51089	0.023152	0.168434	0.046927	0.429693	0.007762	0.101611	0.028077	0.02299	6.371791	70.4138	16.18319	18.39345	10.77029	127.2566
51090	0.022707	0.164984	0.046009	0.42088	0.007609	0.099461	0.027511	0.022548	5.77298	65.47723	13.07373	17.30116	8.793907	122.4972
51091	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51092	0.022119	0.161524	0.04488	0.412092	0.007429	0.097636	0.026899	0.021965	4.352407	87.28494	21.55209	19.27542	14.78836	138.8775
51093	0.021706	0.156766	0.043909	0.399874	0.007254	0.094205	0.026181	0.021554	4.85695	57.54762	11.67384	14.05507	7.897194	105.4559
51094	0.007166	0.052868	0.014581	0.134906	0.002418	0.03213	0.008781	0.007116	3.022166	34.68012	8.170385	8.499085	5.469117	50.91891
51095	0.030199	0.216024	0.06093	0.550932	0.010049	0.129149	0.036167	0.029986	5.254712	67.65492	14.80473	13.97038	10.14215	123.0695
51096	0.015695	0.114511	0.031837	0.292143	0.005269	0.069186	0.019074	0.015585	2.396937	61.75312	15.44306	10.79869	10.69824	105.3271
51097	0.027042	0.195426	0.054713	0.498492	0.00904	0.117475	0.032633	0.026853	5.991449	70.72306	14.43817	17.80979	9.752689	132.2408
51098	0.006657	0.049637	0.013586	0.126685	0.002257	0.030333	0.008222	0.006611	2.794099	27.80828	5.038282	8.667835	3.324342	52.14201
51099	0.005288	0.040932	0.010904	0.104535	0.001824	0.025497	0.006716	0.005252	4.749796	36.97929	6.231151	13.48808	3.910115	64.9541
51100	0.002388	0.018552	0.004929	0.047383	0.000825	0.011577	0.003041	0.002372	2.253306	17.34976	2.813704	6.395384	1.784209	30.44423
51101	0.004276	0.032713	0.008789	0.083529	0.001467	0.020257	0.005384	0.004247	3.23318	26.22036	4.634351	9.199402	2.929507	46.22403
51102	0.006047	0.044929	0.012328	0.114662	0.002047	0.027406	0.007449	0.006005	2.649947	25.14177	4.603122	7.73532	2.978845	45.51713
51103	0.0091	0.068217	0.018598	0.17412	0.003093	0.041803	0.011284	0.009037	4.711763	42.67849	7.597492	13.77494	4.883039	77.05437

The modelled OD matrix was then imported into Microsoft Excel for further analysis. The actual OD matrix was previously discussed and some sections of it were presented in Chapter 5.

Subsequently, the **total** production (trips originated from homes onto the workplaces as outlined in the row of the tables) from the model output was plotted against the total production from the actual data for the purpose of trip-distribution accuracy assessment.

In Figure 7.4, the x-axis demonstrates the total number of home-based work trips and the y-axis demonstrates the total number of home-based work trips extracted from the EMME model.

Figure 7.4: Total home-based work trips – comparison between actual data and EMME model outcomes

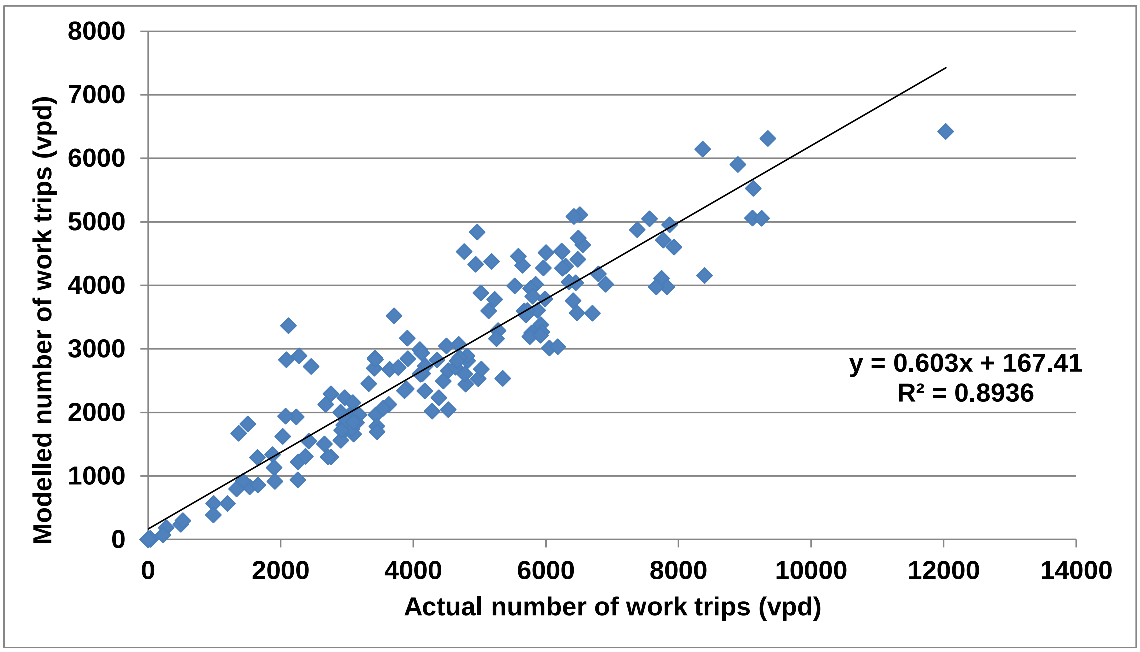


Figure 7.4 confirms the accuracy of the modelled trip distribution in comparison with the actual data. The results of the graph presented in Figure 7.4 show a linear trend line with a R^2 of 0.89, which is considered a very good match in such a large modelling area for the entire Perth and Peel regions. It is noted that the outcome of this analysis (shown in Figure 7.4) provides a strong case to support the trip-distribution calibration undertaken as part of this assessment. It is evident from the analysis that the Gamma function used as part of this assessment could result in a calibrated trip distribution, therefore it can now be claimed

that the trips within this transport model are distributed between origin zones onto the attraction zones in accordance with actual trip distribution in real life. This is a significant achievement to support the outcome of this research with respect to the objectives presented in Chapter 1.

7.4 Summary

The accuracy of the Gamma function proposed for trip distribution as set out in Chapter 5 was again examined by undertaking various tests on the outcomes of the transportation model and comparing the outcomes with the actual information from the DoPLH.

The outcome of the analysis presented in this chapter clarifies the accuracy of the trip-distribution calibration and once more confirms the accuracy of the proposed Gamma function to calibrate the home-based work trips in the Perth metropolitan area.

8 PERFORMANCE OF THE PROPOSED DETERRENCE FUNCTION

So far, the performance of the established distance-deterrence function has been confirmed at a strategic level through the application of a transportation model. Since the trip distribution is deemed well-calibrated, considering a good linear regression between the observed work trip and the modelled work-trip matrices, it is anticipated that the traffic distributed between each pair of zones (on a finer and smaller scale) is also calibrated, and as such reflects the actual work-trip distribution pattern provided by the DoPLH. Assessment of the trip distribution on a small scale is a difficult task, especially when dealing with strategic-scale modelling that also mostly requires Microsimulation packages. However, in the process of reviewing the outcome of the EMME model, this author surprisingly realised that the number of trips distributed between each pair of zones is very close to the actual number of trips between the same zones in real life. Such realisation caused the author to consider this in further detail and add this chapter to the thesis, since the outcome of this analysis carries significant importance.

Accordingly, this chapter undertakes a review of the modelled trip distribution on a **smaller scale**. The author proposes two different, innovative and standalone methodologies for reviewing the outcome of the trip distribution on a smaller scale.

If the outcome of these two standalone methodologies is satisfactory, the following conclusions can be made:

- *The suggested distance-deterrence function is capable of well-calibrating* the work-trip distributions not only at a strategic level, but also on a smaller scale.
- The work trips between each pair of production and attraction zones replicate the actual travel pattern between the two zones on a small scale, which is a significantly important outcome.

- The self-sufficiency of the work-trip distribution modelled on the Gamma function used in the Gravity Model is confirmed. Therefore, it is fair to claim that the model does not distribute the work trips in an unrealistic manner, but rather it distributes them logically and in accordance with the actual observed data in real life.

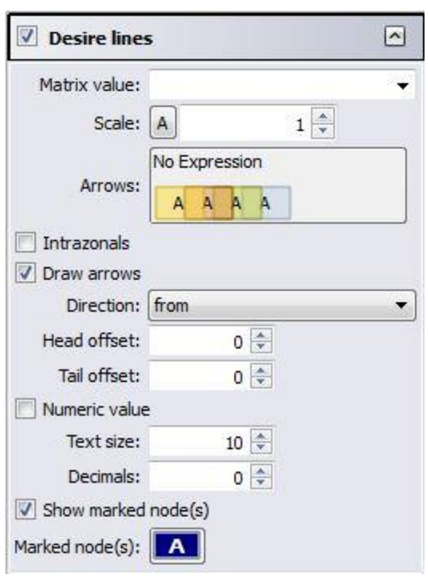
8.1 Methodology 1 – Assessment of the Desire Lines

EMME software allows users to draw Origin and Destination (OD) ***Desire Lines*** to show where the associated traffic to each production or attraction zone is entering or outgoing.

According to the software providers, Desire Lines are commonly used to represent the matrix values between OD pairs. For example, they can represent the magnitude of trip demand from one zone to all other zones. Desire Lines can also be used to visually identify various kinds of connectivity between OD pairs. The thickness of the Desire Line is proportional to the matrix value between the OD pairs. This means that the thicker the Desire Line, the greater number of trips between the respective OD zones.

To display Desire Lines for a selected zone, the user should select Desire Lines in the General worksheet layer control (as shown in Figure 8.1).

Figure 8.1: Desire Line control worksheet



In other words, for a selected production zone the Desire Lines show the destination of traffic which is outgoing from that zone onto the attraction zones; or for an attraction zone, the Desire Line shows the incoming traffic from different associated production zones onto that zone.

In order to assess the trip-distribution performance on a small scale, 10 samples of different residential zones have been selected, and the Desire Lines of the samples have been analysed for work trips.

Ten samples were chosen to undertake this analysis (five from the northern suburbs and five from the southern suburbs) for the purpose of a robust assessment, and to ensure the quality of the work-trip distribution calibration. It was aimed to select the samples from a spread of areas to the north and south of the Swan River.

Samples from the northern suburbs include:

1- Karrinyup – Gwelup – Carine (Residential zone number 51089)

2- Yokine – Coolbinia – Menora (Residential zone number 51097)

3- Bassendean – Eden Hill – Ashfield (Residential zone number 51044)

4- Butler – Merriwa – Ridgewood (Residential zone number 51099)

5- Mosman Park – Peppermint Grove (Residential zone number 51034).

Samples from the southern suburbs include:

1- Canning Vale – West (Residential zone number 51125)

2- Armadale – Wungong – Brookdale (Residential zone number 51110)

3- Spearwood (Residential zone number 51153)

4- Coogee (Residential zone number 51152)

5- Pinjarra (Residential zone number 51029).

For each of the residential samples, the Desire Lines were drawn in EMME. The Desire Line module computes the total outgoing traffic from each residential zone and shows the Desire Lines in a different color-coded format based on the range of the total number of trips. It is noted that EMME distributes the work trips based on the Gravity Model, where trips are proportionally related to size of the zones and inversely proportional to the distances.

Accordingly, for each residential zone the total number of produced trips were computed and two ranges of total number of work trips were specified (0 -50% of the total number of work trips and 50%-100% of the total number of work trips). The analysis of the work-trip distribution is based on the 50% to 100% of the work trips, which contain a higher number of trips and indeed a thicker Desire Line. Subsequently, the total number of trips between each OD zone was extracted from the model and compared with the actual number of trips provided by the DoPLH.

It is noted that the analysis of 50%-100% work trips from each of the residential samples result in a robust assessment, as the traffic impact of the 0-50% of work trips on the road network is considered to be insignificant on a daily or hourly basis.

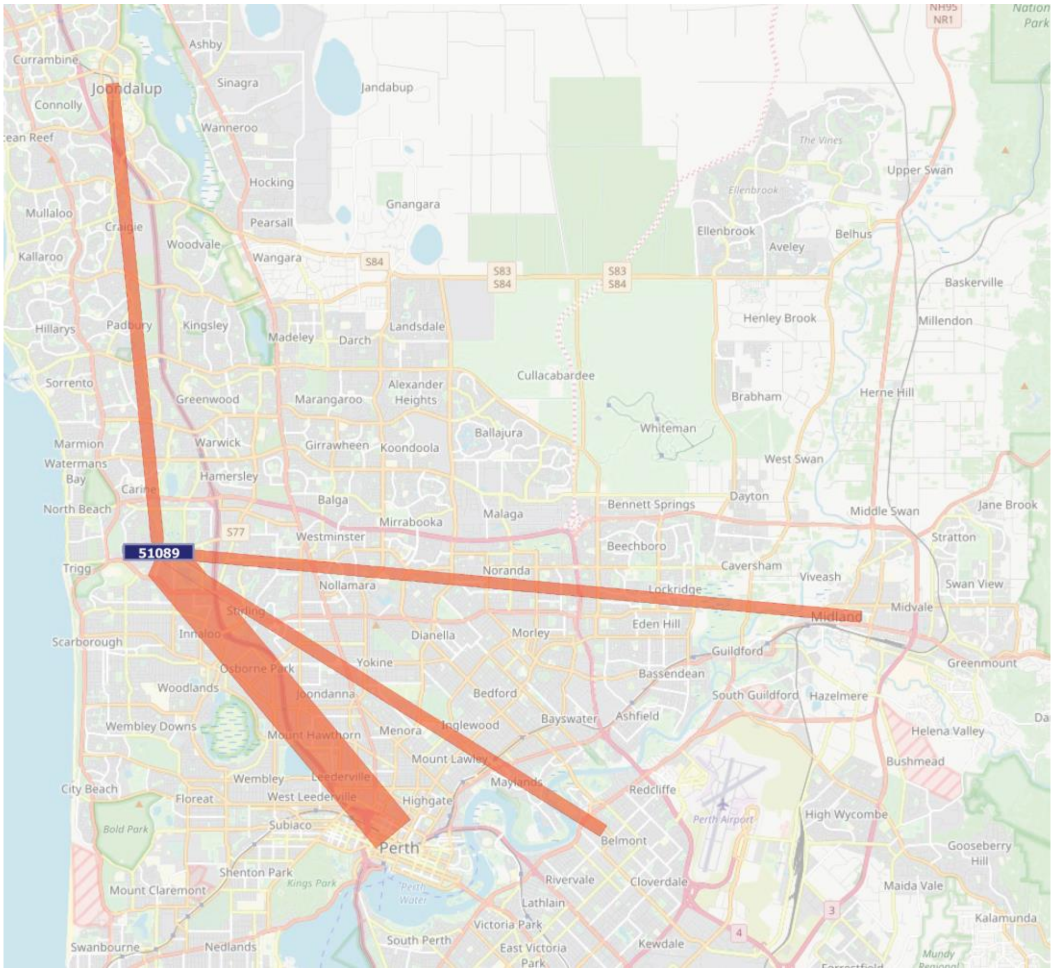
8.1.1 Analysis of the selected samples to the north of Swan River (northern suburbs)

This section will discuss the selected five samples from the northern parcel of Perth (to the north of Swan River). Each sample will be discussed separately and its respective Desire Lines will be extracted from EMME for further discussion and analysis.

Karrinyup – Gwelup – Carine (Residential zone number 51089)

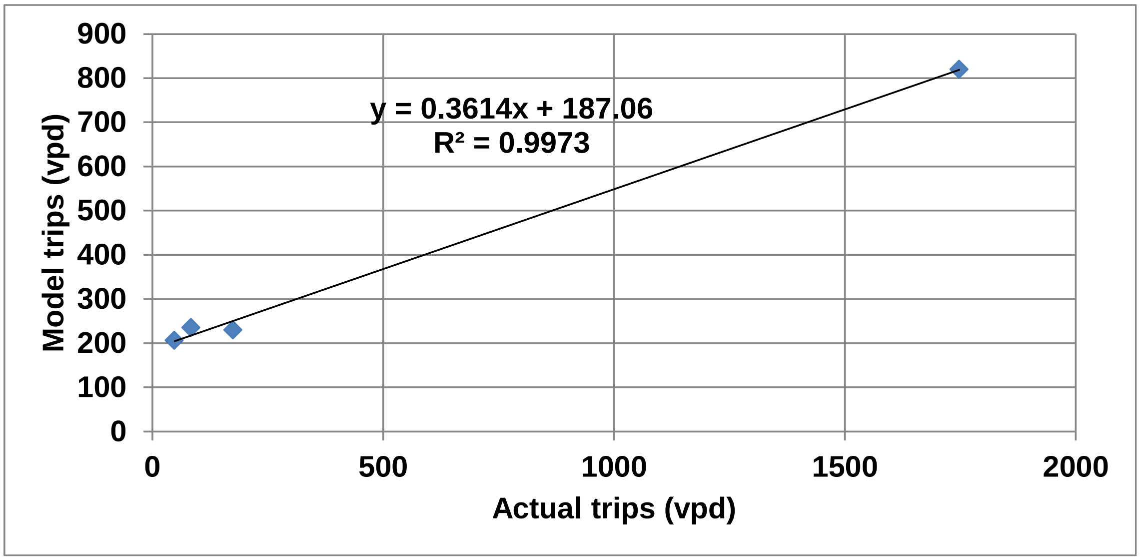
As shown in Figure 8.2, 50% to 100% of the work trips from zone 51089 are distributed onto four attraction zones, and as is logically expected, the maximum number of work trips (thickest Desire Line) are outgoing from the residential zone onto the attraction zone in the Perth CBD. Now that the destination of the work trips is found, the total number of trips from the model are extracted and compared with the actual number of trips in real life provided by the DoPLH. To undertake a comparison study, the modelled number of work trips were plotted against the actual number of work trips in Microsoft Excel and a trend line was established with its associated R^2.

Figure 8.2: Desire Lines for residential zone number 51089



As can be seen in Figure 8.3, the regression follows a perfect linear trend with a value of $R^2 = 0.9973$. This clearly shows the accuracy of the work-trip distribution calibration on a micro scale, and as such it is evident that the proposed Gamma function in use for the trip distribution is quite capable of replicating the actual work-trip distribution.

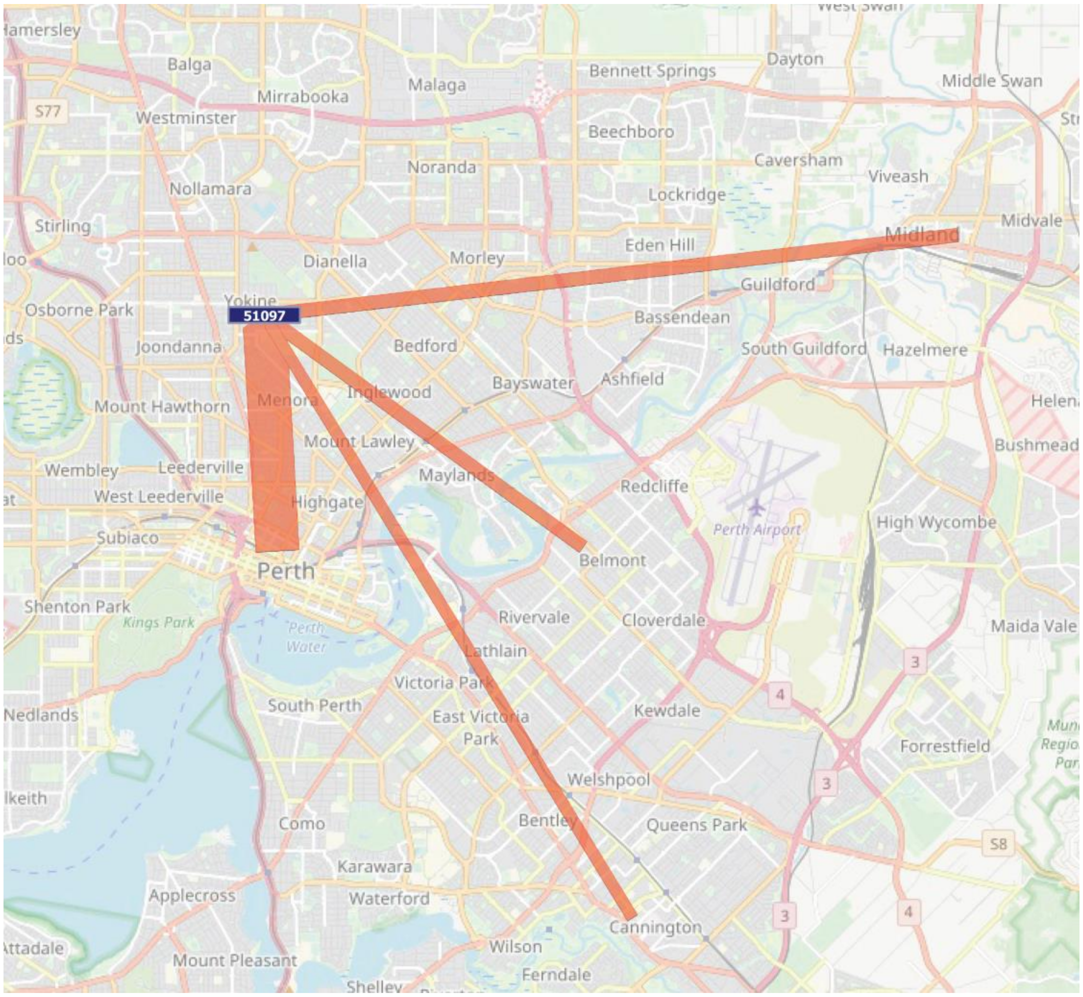
Figure 8.3: Actual and modelled number of trips from zone 51089 onto the attraction zones



Yokine – Coolbinia – Menora (Residential zone number 51097)

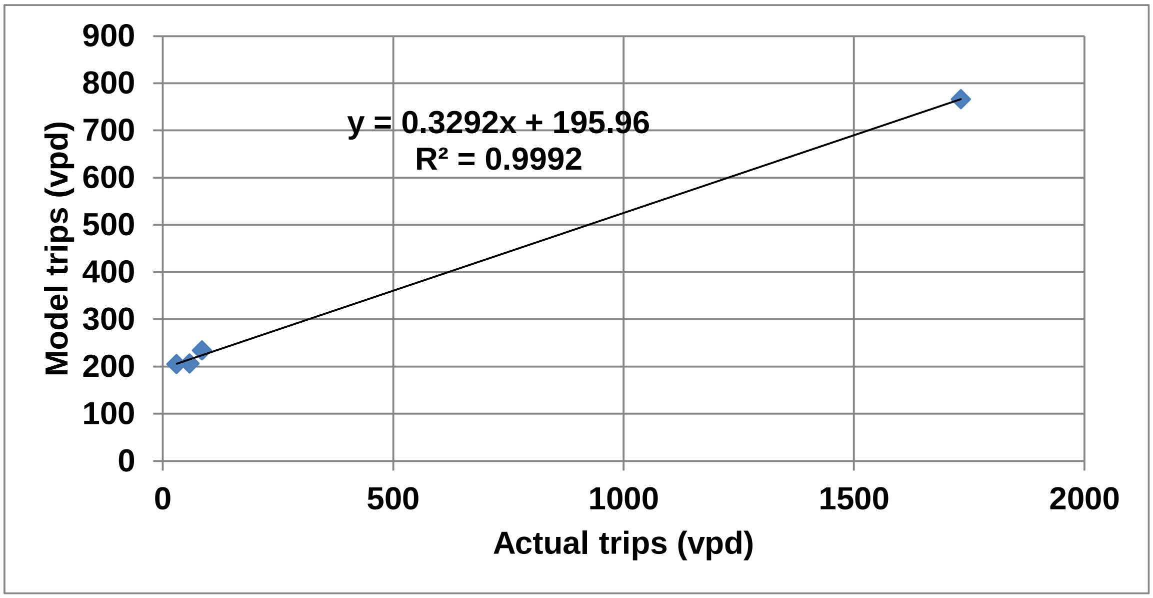
As shown in Figure 8.4, 50% to 100% of the work trips from zone 51097 are distributed onto four attraction zones, and as is logically expected, the maximum number of work trips (thickest Desire Line) is outgoing from the residential zone onto the attraction zone in the Perth CBD. Now that the destination of the work trips is found, the total number of trips from the model are extracted and compared with the actual number of trips in real life, provided by the DoPLH. To undertake a comparison study, the modelled number of work trips were plotted against the actual number of work trips in Microsoft Excel and a trend line was established with its associated R^2.

Figure 8.4: Desire Lines for residential zone number 51097



As can be seen in Figure 8.5, the regression follows a perfect linear trend with a value of $R^2 = 0.9992$. This clearly shows the accuracy of the work-trip distribution calibration on a micro scale, and as such it is evident that the proposed Gamma function in use for the trip distribution is quite capable of replicating the actual work-trip distribution.

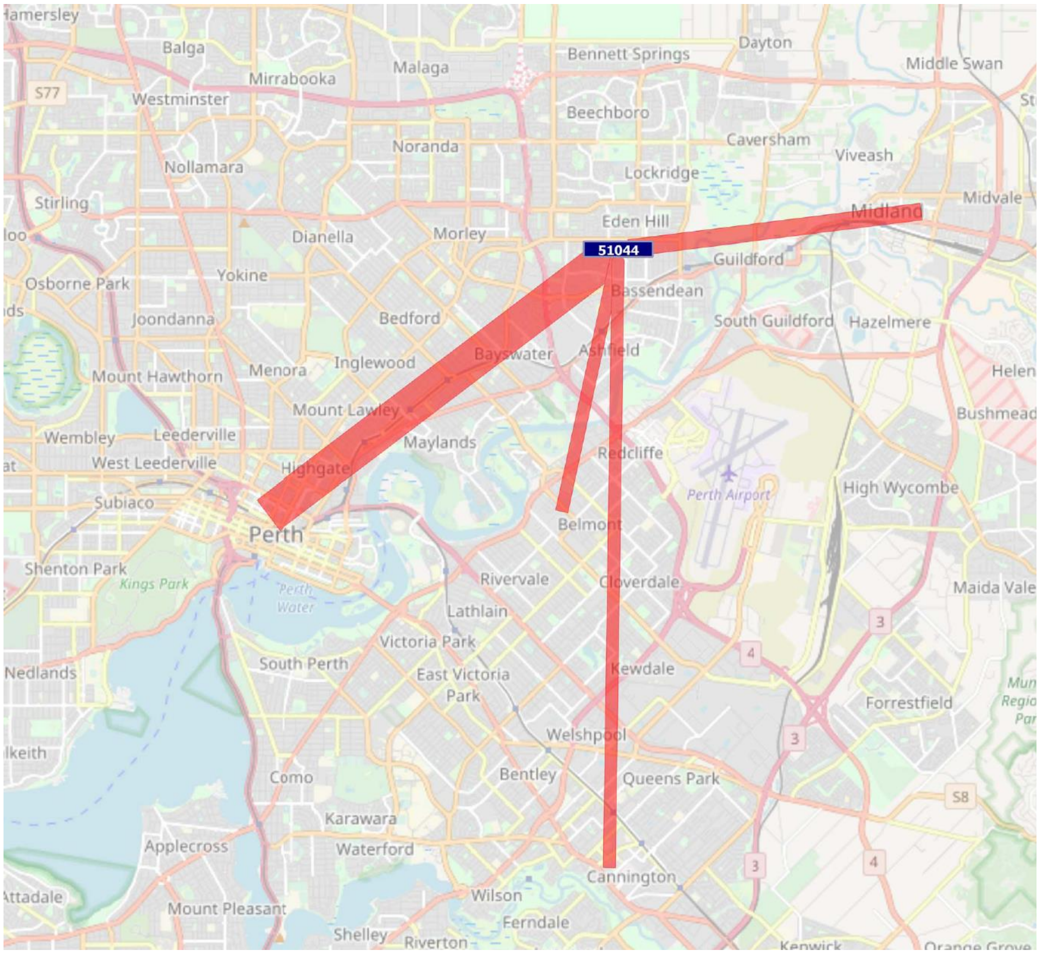
Figure 8.5: Actual and modelled number of trips from zone 51097 onto the attraction zones



Bassendean – Eden Hill – Ashfield (Residential zone number 51044)

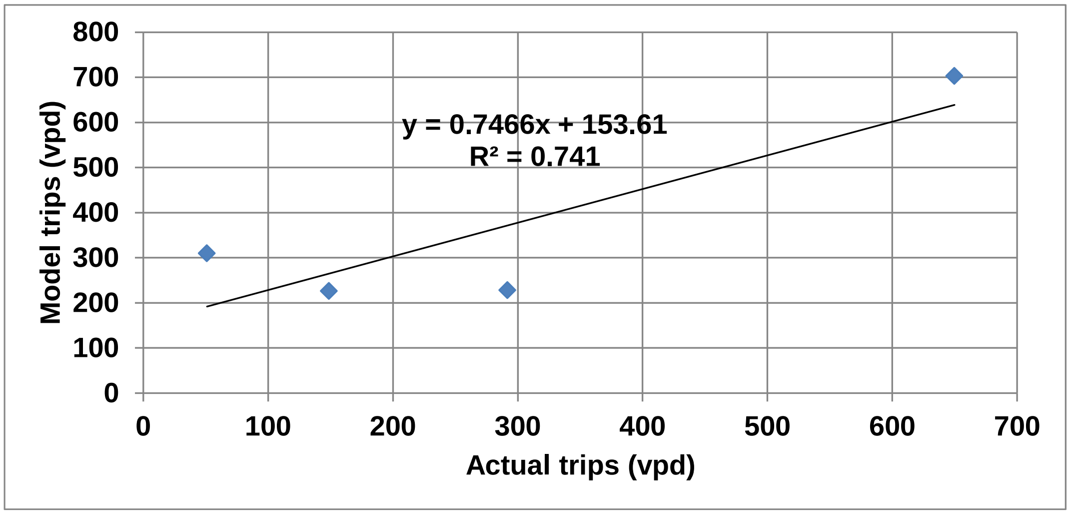
As shown in Figure 8.6, 50% to 100% of the work trips from zone 51044 are distributed onto four attraction zones, and as is logically expected, the maximum number of work trips (thickest Desire Line) is outgoing from the residential zone onto the attraction zone in the Perth CBD. Now that the destination of the work trips is found, the total number of trips from the model are extracted and compared with the actual number of trips in real life, provided by the DoPLH. To undertake a comparison study, the modelled number of work trips were plotted against the actual number of work trips in Microsoft Excel and a trend line was established with its associated R^2.

Figure 8.6: Desire Lines for residential zone number 51044



As can be seen in Figure 8.7, the regression follows a linear trend with a value of $R^2 = 0.741$. This clearly shows the accuracy of the work-trip distribution calibration on a micro scale, and as such it is evident that the proposed Gamma function in use for the trip distribution is quite capable of replicating the actual work-trip distribution.

Figure 8.7: Actual and modelled number of trips from zone 51044 onto the attraction zones

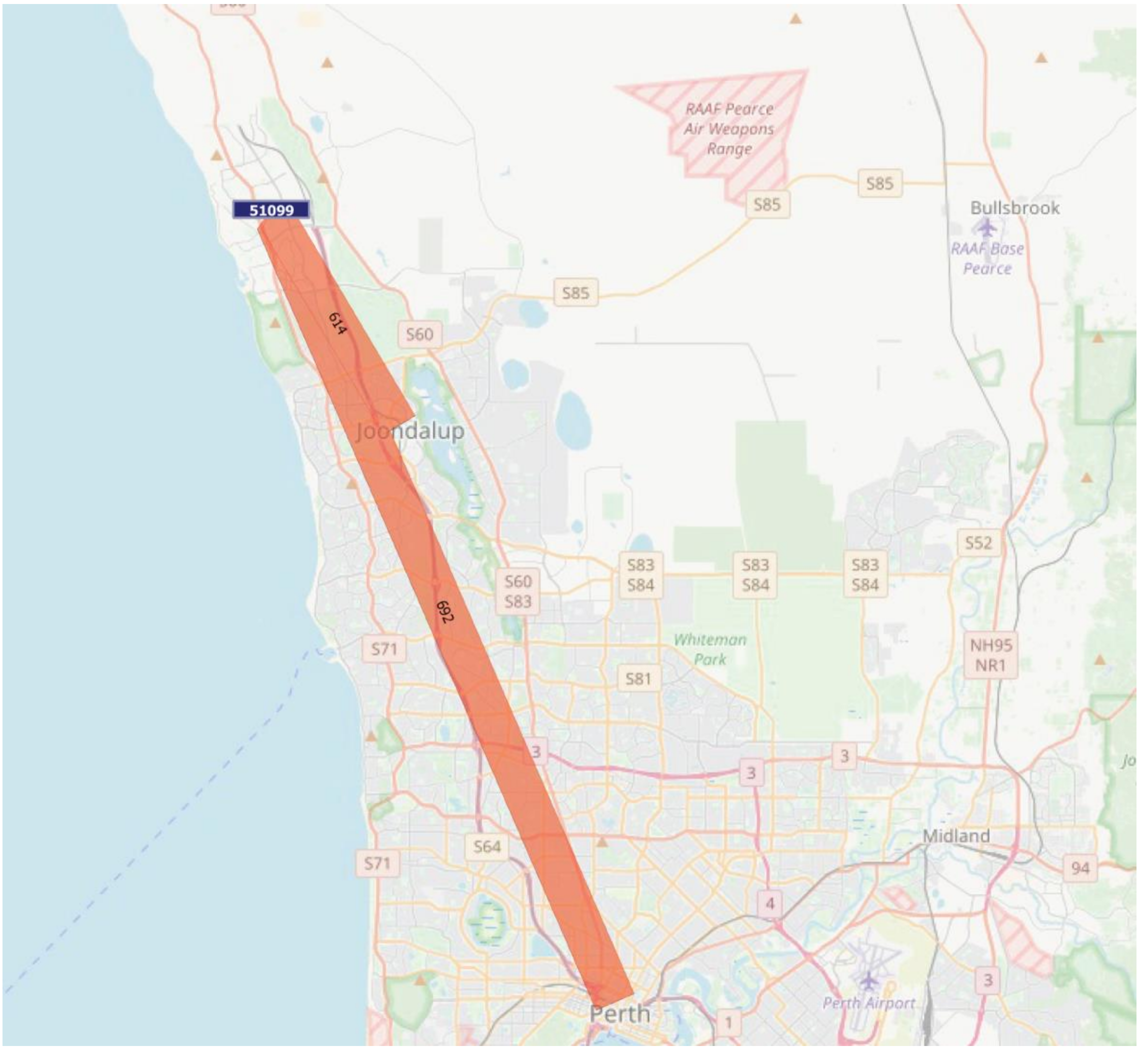


It is noted that although the square root of 0.741 is not as high as the other two residential zones, it is still quite reasonably high in such a large area of modelling. To further support this figure, the author would like to draw attention to the actual and modelled number of trips between zone 51044 and the Perth CBD attraction zone (with the highest number of trips associated to it). The model sends 703vpd trips from Bassendean to the Perth CBD; however, the actual data shows a total of 650vpd, which is quite close, with only a 53vpd discrepancy to the modelled data (703 – 650 = 53vpd).

Butler – Merriwa – Ridgewood (Residential zone number 51099)

As shown in Figure 8.8, 50% to 100% of the work trips from zone 51099 are distributed onto two attraction zones, and as is logically expected, the maximum number of work trips (thickest Desire Line) is outgoing from the residential zone onto the attraction zone in the Perth CBD. Now that the destination of the work trips is found, the total number of trips from the model are extracted and compared with the actual number of trips in real life, provided by the DoPLH. To undertake a comparison study, the modelled number of work trips were reviewed against the actual number of work trips; however, as the number of trips is this time distributed only between two major zones (Perth CBD and Joondalup), the regression analysis is not shown as a trend line, for two data is obviously linear with the square root of 1.

Figure 8.8: Desire Lines for residential zone number 51099



As shown in Table 8.1 the difference between the actual trips and modelled trips distributed from zone 51099 to the Perth CBD is (769-692=77vpd), and the difference between the actual trips and modelled trips distributed from zone 51099 to Joondalup is (683-614=66vpd). Accordingly, the differences are quite low, which again strongly confirms the accuracy of the model distribution for work trips.

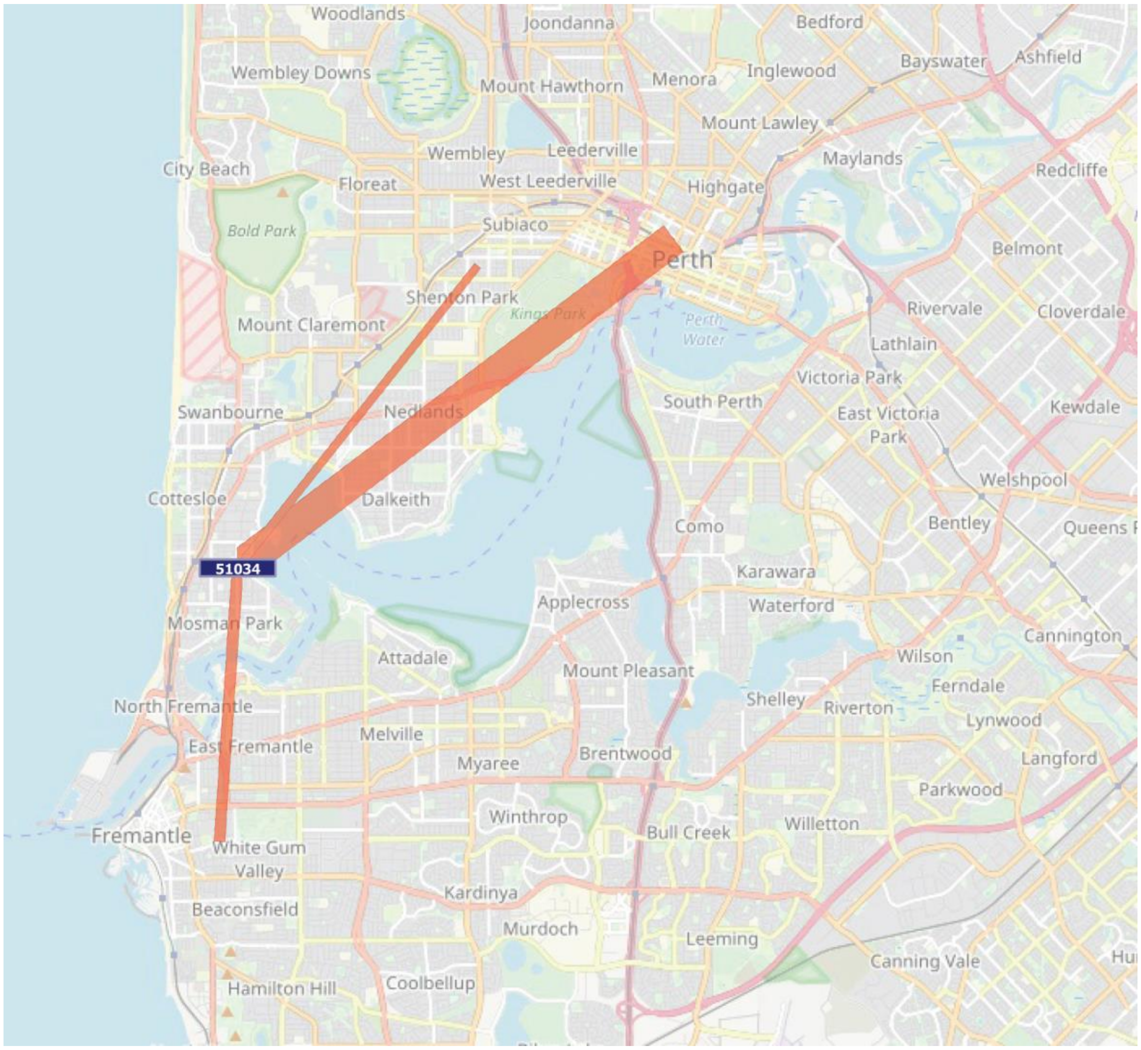
Table 8.1: Number of work trips (Actual and Modelled (vpd))

Actual (vpd)	100041 (City of Perth)	100077 (Joondalup)
51099 (Butler - Merriwa - Ridgewood)	769	683
Model (vpd)	100041 (City of Perth)	100077 (Joondalup)
51099 (Butler - Merriwa - Ridgewood)	692	614

Mosman Park – Peppermint Grove (Residential zone number 51034)

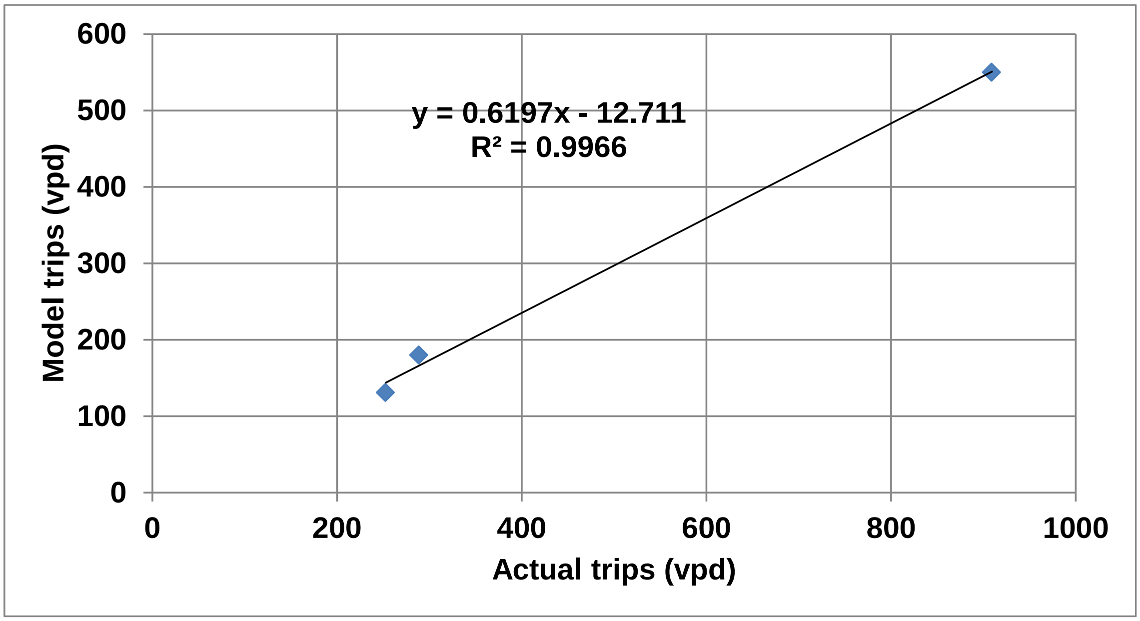
As shown in Figure 8.9, 50% to 100% of the work trips from zone 51034 are distributed onto three attraction zones, and as is logically expected, the maximum number of work trips (thickest Desire Line) is outgoing from the residential zone onto the attraction zone in the Perth CBD. Now that the destination of the work trips is found, the total number of trips from the model are extracted and compared with the actual number of trips in real life, provided by the DoPLH. To undertake a comparison study, the modelled number of work trips were plotted against the actual number of work trips in Microsoft Excel and a trend line was established with its associated R^2.

Figure 8.9: Desire Lines for residential zone number 51034



As can be seen in Figure 8.10, the regression follows a perfect linear trend with a value of $R^2 = 0.9966$. This clearly shows the accuracy of the work-trip distribution calibration on a micro scale, and as such it is evident that the proposed Gamma function in use for the trip distribution is quite capable of replicating the actual work-trip distribution.

Figure 8.10: Actual and modelled number of trips from zone 51034 onto the attraction zones



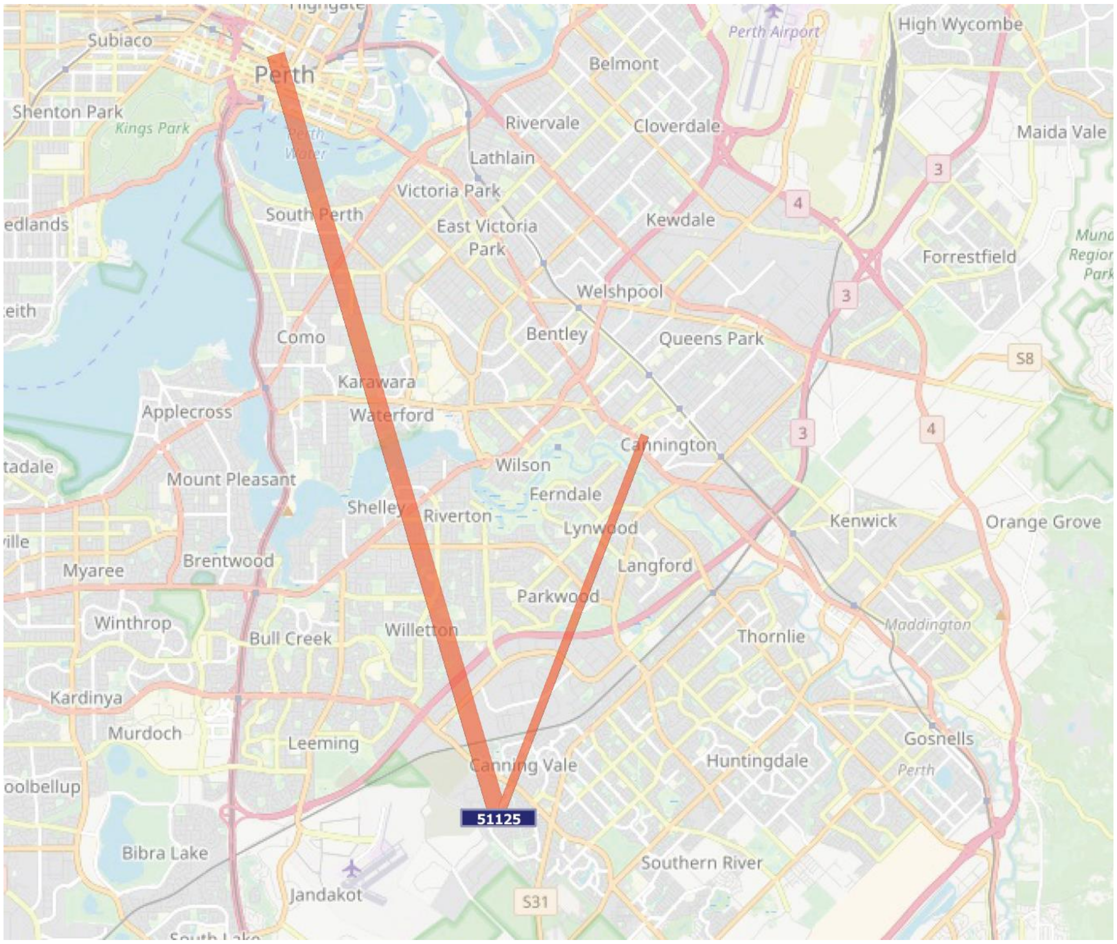
8.1.2 Analysis of the selected samples to the south of Swan River (southern suburbs)

This section will discuss the selected five samples from the southern parcel of Perth (to the south of Swan River). Each sample will be discussed separately and its respective Desire Lines will be extracted from EMME for further discussion and analysis.

Canning Vale – West (Residential zone number 51125)

As shown in Figure 8.11, 50% to 100% of the work trips from zone 51125 are distributed onto two attraction zones, and as is logically expected, the maximum number of work trips (thickest Desire Line) is outgoing from the residential zone onto the attraction zone in the Perth CBD. Now that the destination of the work trips is found, the total number of trips from the model are extracted and compared with the actual number of trips in real life, provided by the DoPLH. To undertake a comparison study, the modelled number of work trips were reviewed against the actual number of work trips; however, as the number of trips is this time distributed only between two major zones (Perth CBD and Cannington), the regression analysis is not shown as a trend line, for two data is obviously linear with the square root of 1.

Figure 8.11: Desire Lines for residential zone number 51125



As shown in Table 8.2, the difference between the actual trips and modelled trips distributed from zone 51125 to the Perth CBD is (723-306=417vpd), and the difference between the actual trips and modelled trips distributed from zone 51125 to Cannington is (147-141=6vpd). Accordingly, the differences are quite low, which again strongly confirms the accuracy of the model distribution for work trips.

Table 8.2: Number of work trips (Actual and Modelled (vpd))

Actual (vpd)	100041 (City of Perth)	100127 (Cannington)
51125 (Canning Vale - West)	723	147
Model (vpd)	100041 (City of Perth)	100127 (Cannington)
51125 (Canning Vale - West)	306	141

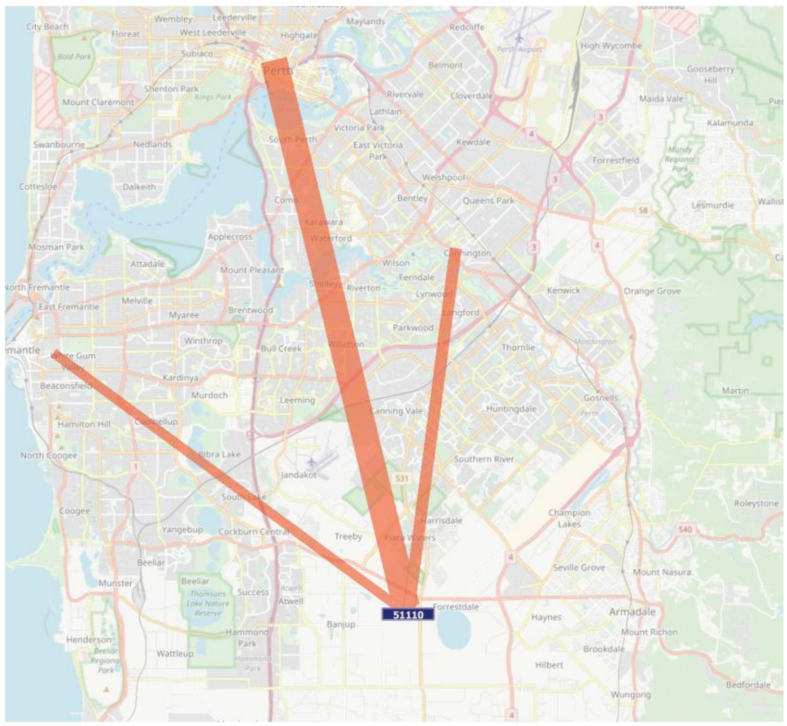
It is noted that Cannington is a great attractor of work trips, with a large number of commercial activities that absorb numerous work trips. In this instance, and as Canning Vale is quite close to Cannington (about 7km), the trips are well distributed from this zone onto the Cannington commercial zone (96% accurate). However, it is evident from the total number of modelled work trips that the model still sends a reasonable amount of work trips towards the Perth CBD (about 2.16 times more than work trips in Cannington), which confirms that the Gravity Model works significantly accurately in consideration of the proposed Gamma function introduced to it. The difference observed between the modelled and actual work trips between Canning Vale and Perth CBD suggests that the model is sensitive and responsive to the distance of travel as well as the greatness of the production and attraction zones which are both considered as the main factors in the Gravity Model. It is to be noted that the Canning Vale is located about 15km towards south of Perth CBD.

The difference of 6vpd between the actual and modelled trips between Canning Vale and Cannington is a measure of the accuracy of the trip-distribution calibration and should be fleshed out as a significantly valuable outcome of this thesis. Such microscopic detail of calibration through strategic modelling is rare and confirms the importance of calibrating the deterrence functions in Gravity Models.

Armadale – Wungong – Brookdale (Residential zone number 51110)

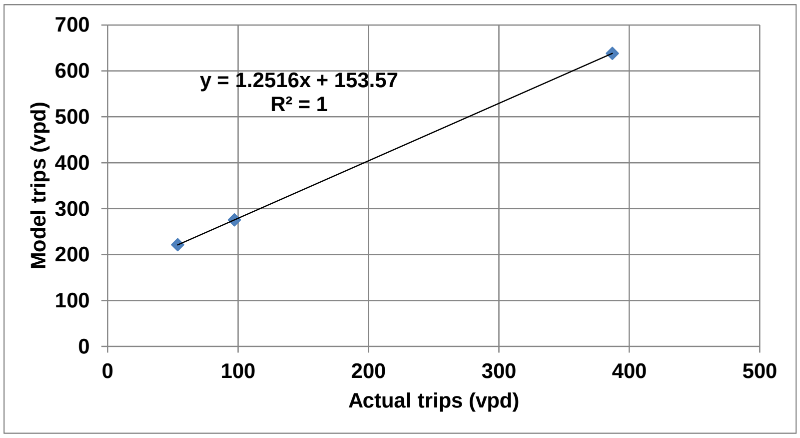
As shown in Figure 8.12, 50% to 100% of the work trips from zone 51110 are distributed onto three attraction zones, and as is logically expected, the maximum number of work trips (thickest Desire Line) is outgoing from the residential zone onto the attraction zone in the Perth CBD. Now that the destination of the work trips is found, the total number of trips from the model are extracted and compared with the actual number of trips in real life, provided by the DoPLH. To undertake a comparison study, the modelled number of work trips were plotted against the actual number of work trips in Microsoft Excel and a trend line was established with its associated R^2.

Figure 8.12: Desire Lines for residential zone number 51110



As can be seen in Figure 8.13, the regression follows a perfect linear trend with a value of $R^2 = 1$. This clearly shows the accuracy of the work-trip distribution calibration on a micro scale, and as such it is evident that the proposed Gamma function in use for the trip distribution is quite capable of replicating the actual work-trip distribution.

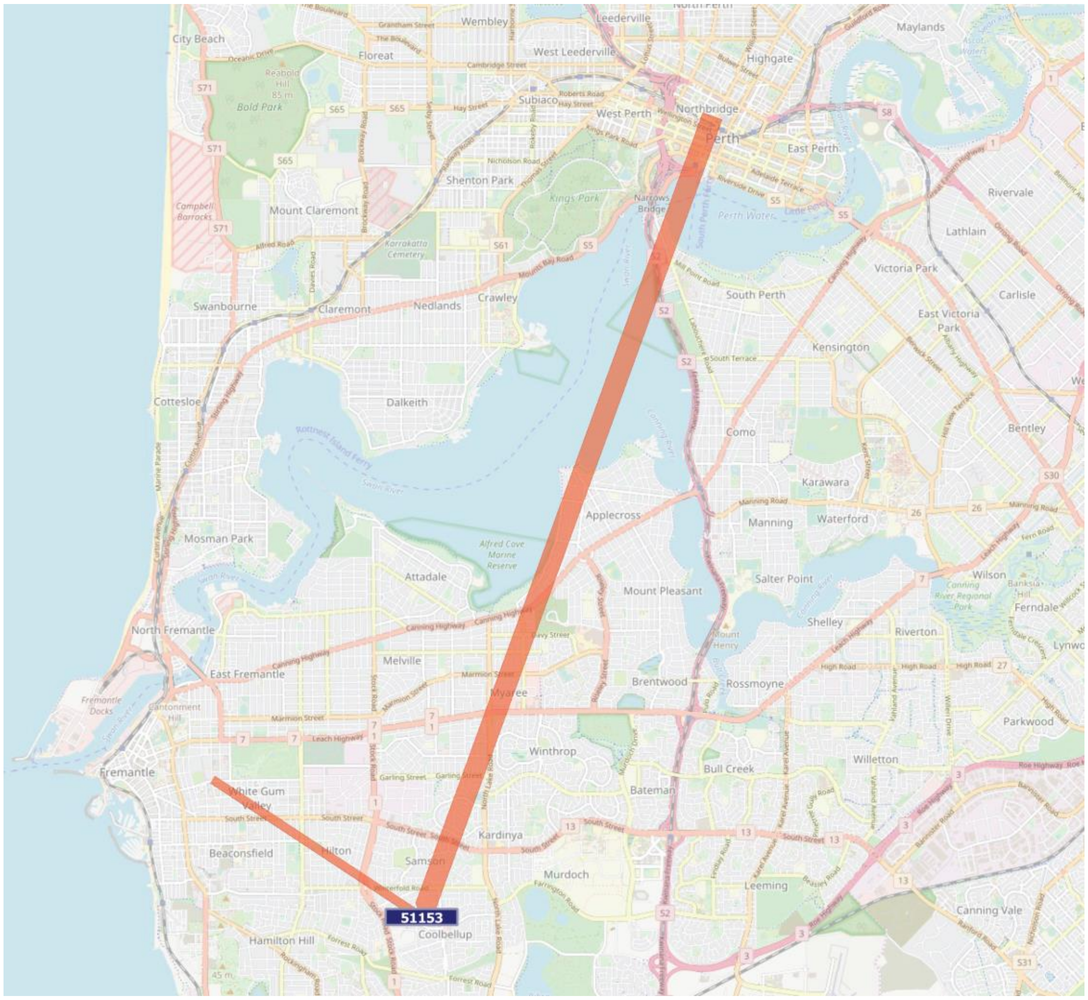
Figure 8.13: Actual and modelled number of trips from zone 51110 onto the attraction zones



Spearwood (Residential zone number 51153)

As shown in Figure 8.14, 50% to 100% of the work trips from zone 51153 are distributed onto two attraction zones, and as is logically expected, the maximum number of work trips (thickest Desire Line) is outgoing from the residential zone onto the attraction zone in the Perth CBD. Now that the destination of the work trips is found, the total number of trips from the model are extracted and compared with the actual number of trips in real life, provided by the DoPLH. To undertake a comparison study, the modelled number of work trips were reviewed against the actual number of work trips; however, as the number of trips is this time distributed only between two major zones (Perth CBD and Fremantle), the regression analysis is not shown as a trend line, for two data is obviously linear with the square root of 1.

Figure 8.14: Desire Lines for residential zone number 51153



As shown in Table 8.3, the difference between the actual trips and modelled trips distributed from zone 51153 to the Perth CBD is (354-360 = -4vpd), and the difference between the actual trips and modelled trips distributed from zone 51153 to Fremantle is 202-295 = 93vpd. Accordingly, the differences are quite low, which again strongly confirms the accuracy of the model distribution for work trips. As is apparent from the results of the analysis, the model distributes four more trips to the CBD compared to actual information. However, the discrepancy is negligible and the calibration of trip distribution is explicitly obvious.

Table 8.3: Number of work trips (Actual and Modelled (vpd))

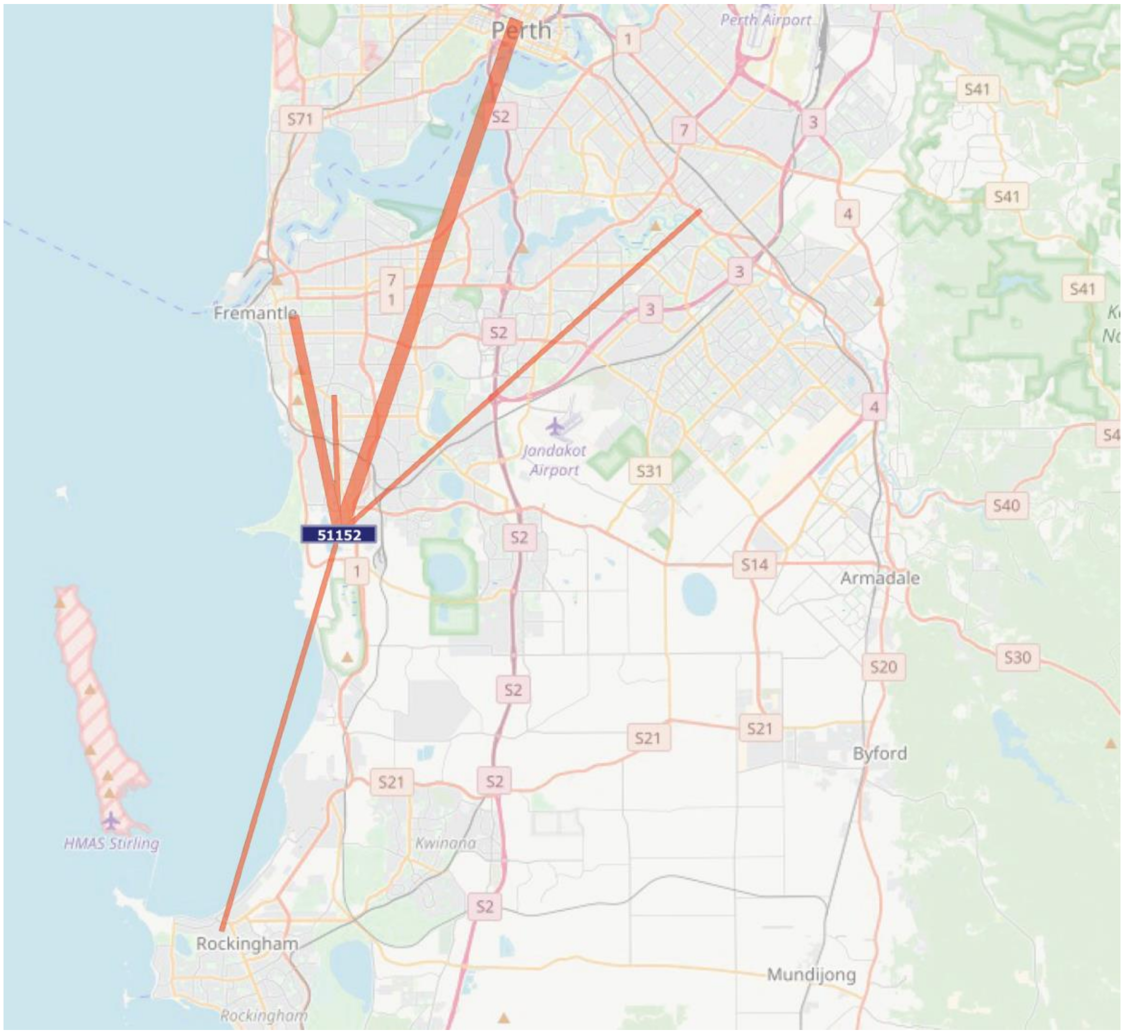
Actual (vpd)	100041 (City of Perth)	100165 (Fremantle)
51153 (Spearwood)	354	295
Model (vpd)	100041 (City of Perth)	100165 (Fremantle)
51153 (Spearwood)	360	202

The difference of only 4vpd between the actual and modelled trips between Spearwood and the CBD is a measure of the accuracy of the trip-distribution calibration and should be fleshed out as a significantly valuable outcome of this thesis. Such microscopic detail of calibration through strategic modelling is rare and confirms the importance of deterrence functions in Gravity Models.

Coogee (Residential zone number 51152)

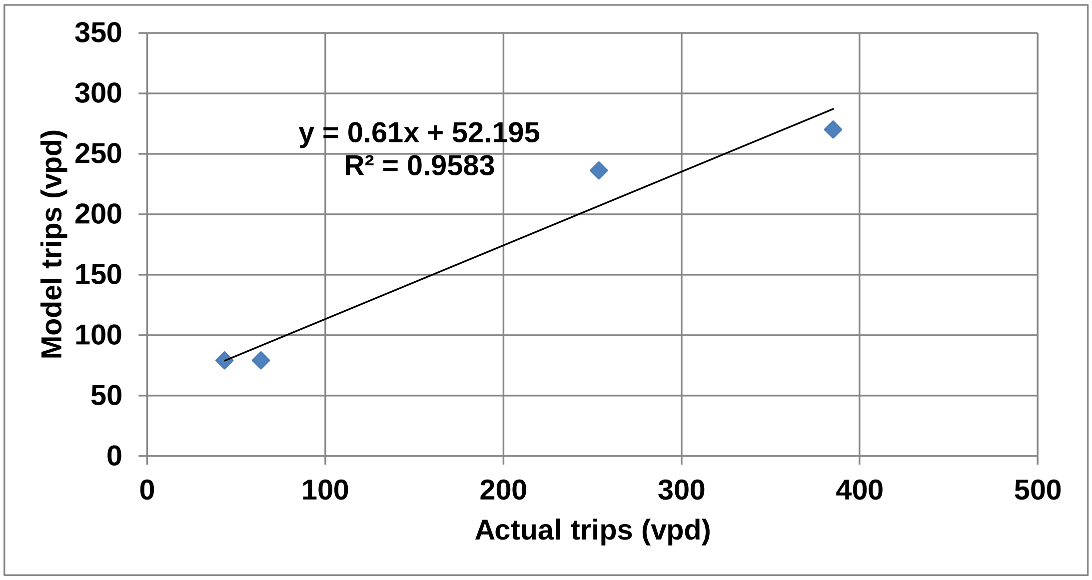
As shown in Figure 8.15, 50% to 100% of the work trips from zone 51152 are distributed onto five attraction zones, and as is logically expected, the maximum number of work trips (thickest Desire Line) is outgoing from the residential zone onto the attraction zone in the Perth CBD. Now that the destination of the work trips is found, the total number of trips from the model are extracted and compared with the actual number of trips in real life, provided by the DoPLH. To undertake a comparison study, the modelled number of work trips were plotted against the actual number of work trips in Microsoft Excel and a trend line was established with its associated R^2.

Figure 8.15: Desire Lines for residential zone number 51152



As can be seen from Figure 8.16, the regression follows a perfect linear trend with a value of $R^2 = 0.9583$. This clearly shows the accuracy of the work-trip distribution calibration on a micro scale, and as such it is evident that the proposed Gamma function in use for the trip distribution is quite capable of replicating the actual work-trip distribution.

Figure 8.16: Actual and modelled number of trips from zone 51152 onto the attraction zones

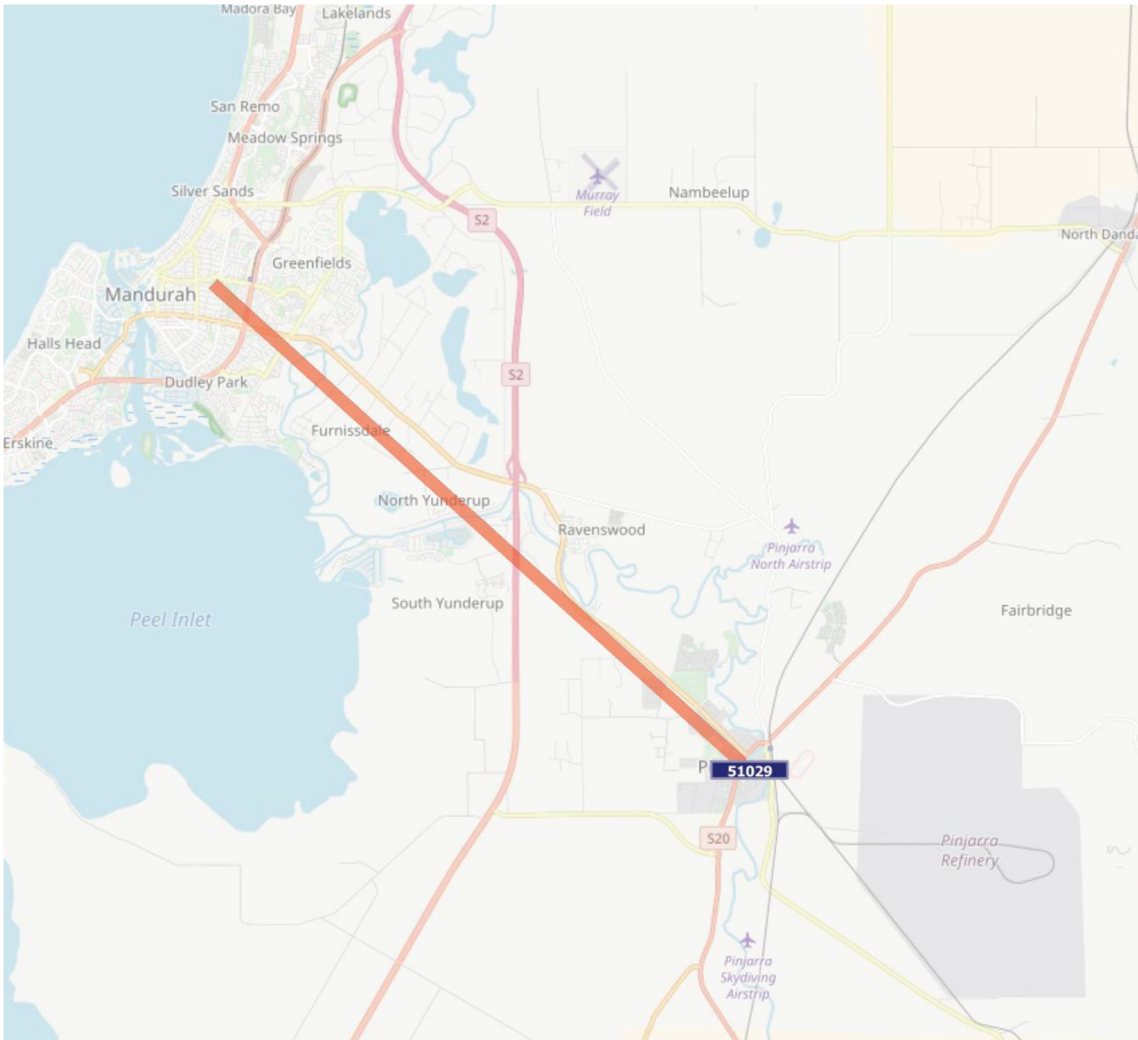


Pinjarra (Residential zone number 51029);

The fifth sample is taken from outside the Perth metropolitan area and within the Peel region to assess the work-trip distribution. As evident in Figure 8.17, the work trips are distributed towards the only close commercial attraction zone within the modelling area, which is in Mandurah. The outcome of the modelling illustrates 200vpd from zone 51029 to Mandurah, whereas the DoPLH data indicates a total of 222vpd, which translates into a negligible difference between the model outputs and the actual trips (222-200=22vpd). Therefore, it can be concluded that the work trips also follow a reasonably good calibration, even outside the metropolitan area.

In all the above 10 samples, it is evident from the Desire Line figures that the model does not distribute the 50% to 100% of work trips across unnecessarily far distances. Therefore, it can visually be concluded that not only do the total trips match the actual work trips data, but also the distances of travel between OD zones are also realistic in the model – which again confirms the accuracy of the proposed Gamma function used for the trip distribution. This confirms the self-sufficiency of the work trips in the model, which demonstrates that the modelled work-trip commuters do not travel unrealistically far distances to travel to work. In other words, the Gamma function used in the Gravity Model could improve the self-sufficiency of the model through distributing the work trips as per the actual work-trip length information.

Figure 8.17: Desire Lines for residential zone number 51029



Methodology 1 aimed to compare the total number of modelled and actual work trips. However, Methodology 2 has been developed to analyse the trip-length calibration and will place more weight on distances of travel rather than on number of trips.

8.2 Methodology 2 – Select Link Analysis

Select Link analysis is a path-based analysis tool which enables users to see where the incoming or outgoing traffic to and from a production or attraction zone is throughout the network. The Select Link analysis can be done on different links with special attributes. For the purpose of our analysis, four different samples of attraction zones have been selected to assess the distance of travel for the 50% to 100% of work commuters into that zone. Again, two non-residential zones have been selected from the northern suburbs and two non-residential zones have been selected from the southern suburbs, to ensure a robust assessment.

Samples from the northern suburbs include:

1 Malaga (Non-residential zone number 100063).

2 Balcatta – Hamersley (Non-residential zone number 100084).

Samples from the southern suburbs include:

1- Maddington – Orange Grove – Martin (Non-residential zone number 100136).

2- South Lake – Cockburn Central (Non-residential zone number 100159).

Before undertaking the fixed-demand traffic assignment, and in order to run a Select Link analysis, an additional attribute for the centroid connectors relevant to the attraction zone which is under assessment should be defined in EMME network Editor. The additional attributes for links are named as ul1, ul2 and ul3. The initial step is to make sure that the proposed attribute is zero for all the other zone connectors within the network. Let us assume that the additional attribute to assist with the Select Link analysis is ul1. To do that, a calculation of ul1=0 should be run for the entire network to ensure all the links have the same value of 0 for ul1 (this task can be done in EMME Network Calculator). Subsequently, the user should choose all the centroid connectors to and from the zone which is due for assessment, and change all ul1(s) to 1. The software is then prepared for a Select Link assessment.

Select Links should be run during the fixed-demand assignment step in EMME as per the following commands in EMME prompt:

Note: the selected options are highlighted in red.

1- Run 5.11 to start an assignment

Select: Type of assignment

1= fixed demand traffic assignment

2= fixed demand transit assignment

3= variable demand traffic assignment

4= end

Select option 1 and run a new assignment

Select: 1= single class assignment on auto mode

2= single class assignment with generalized cost

3= multiclass assignment

4= multiclass assignment with generalized cost

5= generalized cost multiclass assignment with class specific volumes

6= generalized cost multiclass assignment with path analysis

Select: Source for additional volumes

1= no additional volumes

2= auto equivalent of transit vehicles

3= user data on links and turns

4= transit vehicles and user data

5= assign additional demand (additional options assignment)

Select number 5 and introduce the input matrix for distribution (matrix of work trips in this instance to account only for work trips).

Select: Source for additional attributes

1= link user data UL1

2= link user data UL2

3= link user data UL3

4= link length

5= none (no additional path attributes calculated)

6= link user data, length or extra link attribute

7= additional attributes on links and turns

Select number 1, as it is assumed that the additional centroid connector attribute to assist with Select Link analysis is UL1.

Enter: Operator to compute additional path attributes=+

Select + to be used as the operator.

Enter: Lower, upper threshold for active paths

Select 1 to choose the lower threshold for active paths.

The fixed-demand assignment is now concluded and the model is ready for a standard trip assignment following command 5.21, which makes the software run 100 iterations to minimise the time of travel between ODs.

8.2.1 Analysis of the selected samples to the north of Swan River (northern suburbs)

Two samples have been selected from the northern suburbs. Consideration in choosing the samples has been given to the density of the non-residential zones with higher demand for work trips. The focus of this methodology is to assess the trip lengths and not the number of trips attracted to each zone.

Malaga (Non-residential zone number 100063)

The Select Link analysis procedure outlined earlier is provided in detail for zone 100063, which is as follows:

- All the zone connectors in and out of this zone have been chosen and an attribute of ul1=1 was assigned to them (as shown in Figure 8.18).
- The Select Link analysis for this zone was then run in EMME prompt following modules 5.11 and 5.21.
- The result of the Select Link analysis for work trips into this zone is shown in Figure 8.19.

Figure 8.18: Zone connectors for zone number 100063

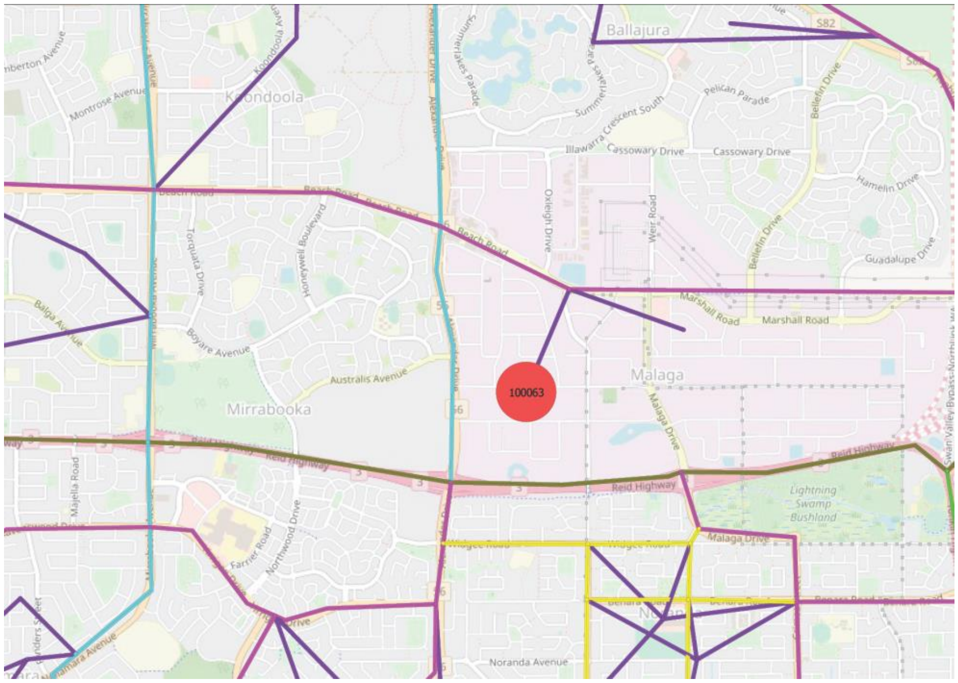


Figure 8.19: Select Link analysis results for zone 100063

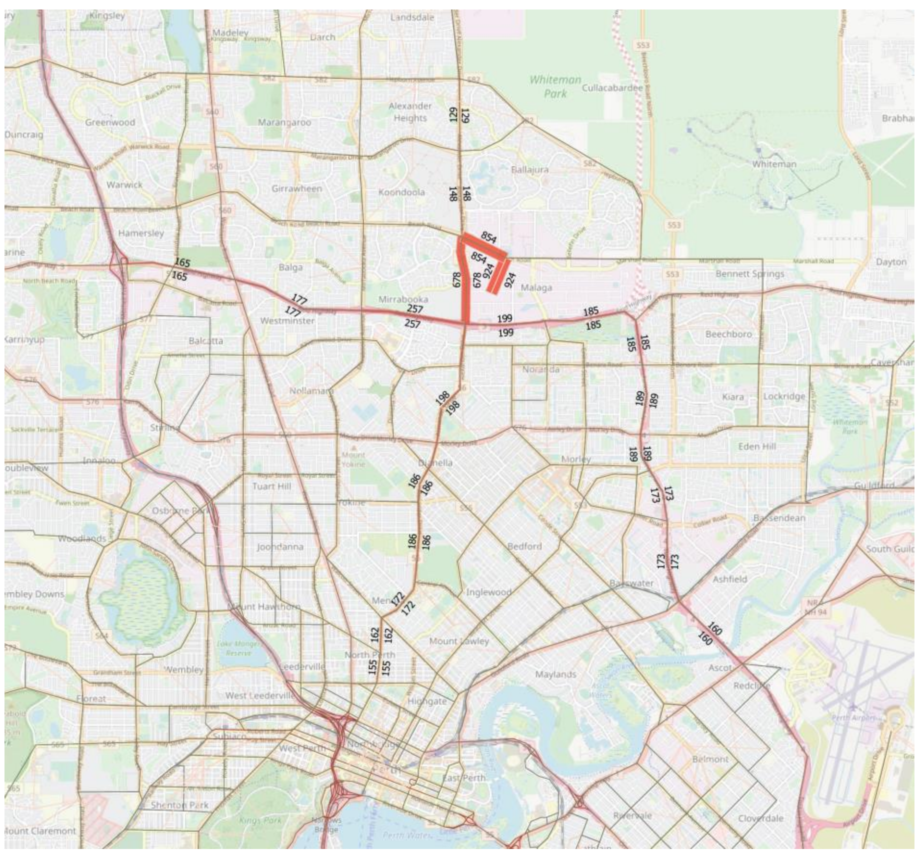
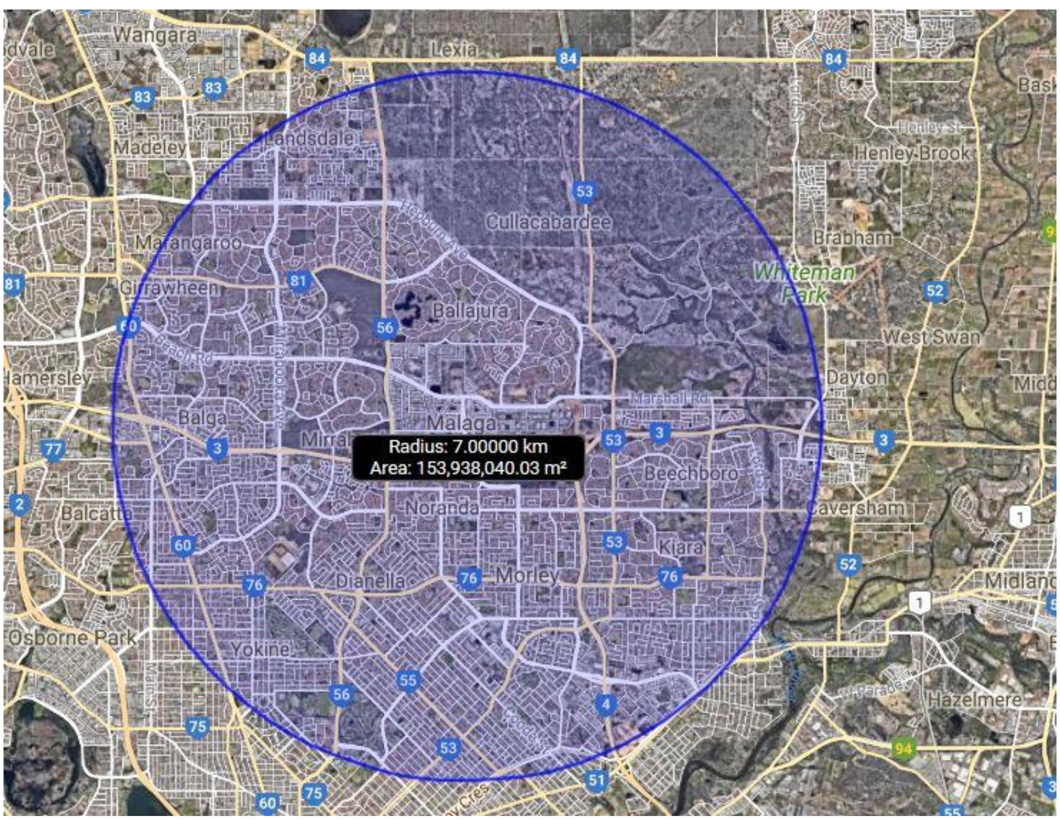


Figure 8.19 contains significantly important information about the distances of travel associated with the work trips attracted by this zone. This figure shows the boundary of the travel distances onto this zone. It is evident from Figure 8.19 that the longest distance of travel for work commuters into zone 100063 is from Ascot and Ashfield areas to the south, and Landsdale area to the north. Figure 8.19 also shows the routes which have been chosen by the commuters to work. Accordingly, the most attractive route of travel into zone 100063 is from Tonkin Highway from south and south-east areas, Alexander Drive from central areas, the extension of Alexander Drive from the north, and Reid Highway from east and west.

As the boundaries of the attractions to zone 100063 have been established, it is now time to analyse the trip length. In order to find the trip lengths, a hypothetical circle is drawn, with the centre of the circle chosen to be on zone 100063 (Malaga area) via Nearmap. This hypothetical circle covers the area bounded by the incoming traffic (as shown in Figure 8.20).

Figure 8.20: Trip length coverage for the attracted traffic to zone 100063



The hypothetical circle shown in Figure 8.20 covers the boundaries of the areas commuted by the work trip travellers associated with zone 100063. According to Figure 8.20, the radius of the circle is 7 km. This means that more than 50% of work commuters to zone 100063 prefer to travel to this zone for work within a maximum distance of 7 km.

Balcatta – Hamersley (Non-residential zone number 100084)

The Select Link analysis procedure outlined earlier is provided in detail for zone 100084, which is as follows:

- All the zone connectors in and out of this zone have been chosen and an attribute of ul1=1 assigned to them (as shown in Figure 8.21).
- The Select Link analysis for this zone was then run in EMME prompt following modules 5.11 and 5.21.
- The result of the Select Link analysis for work trips into this zone is shown in Figure 8.22.

Figure 8.21: Zone connectors for zone number 100084

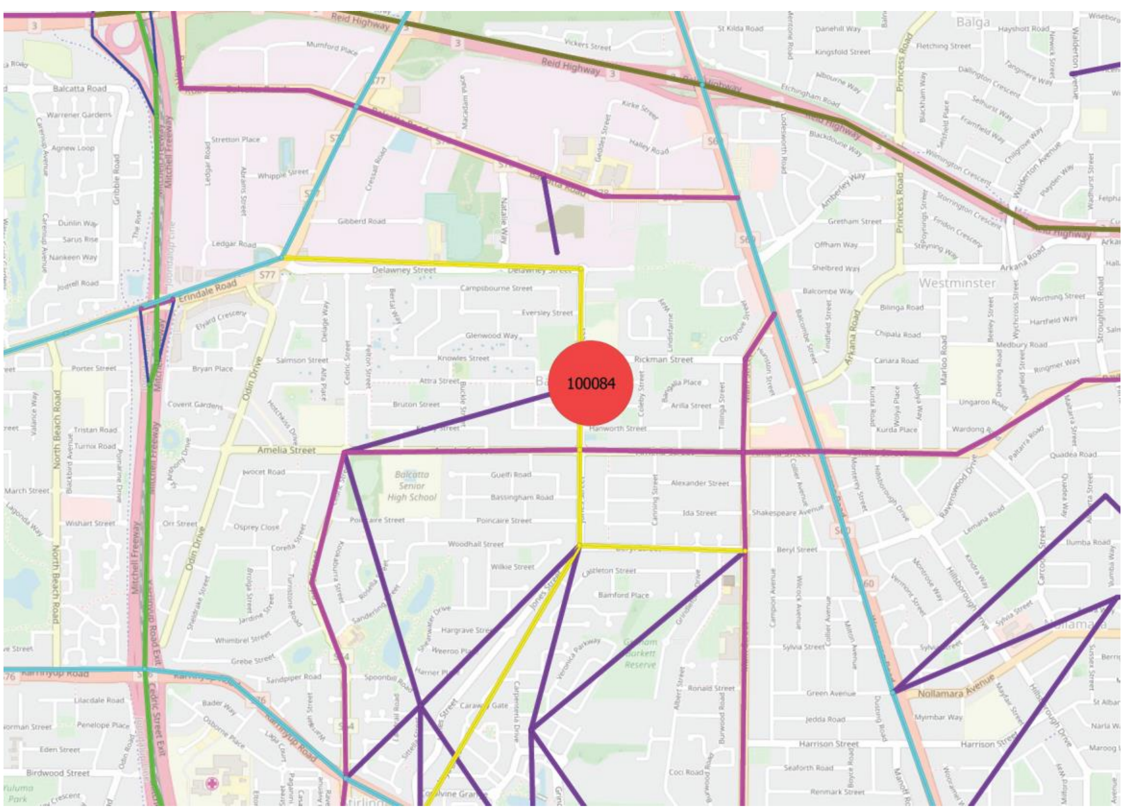


Figure 8.22: Select Link analysis results for zone 100084

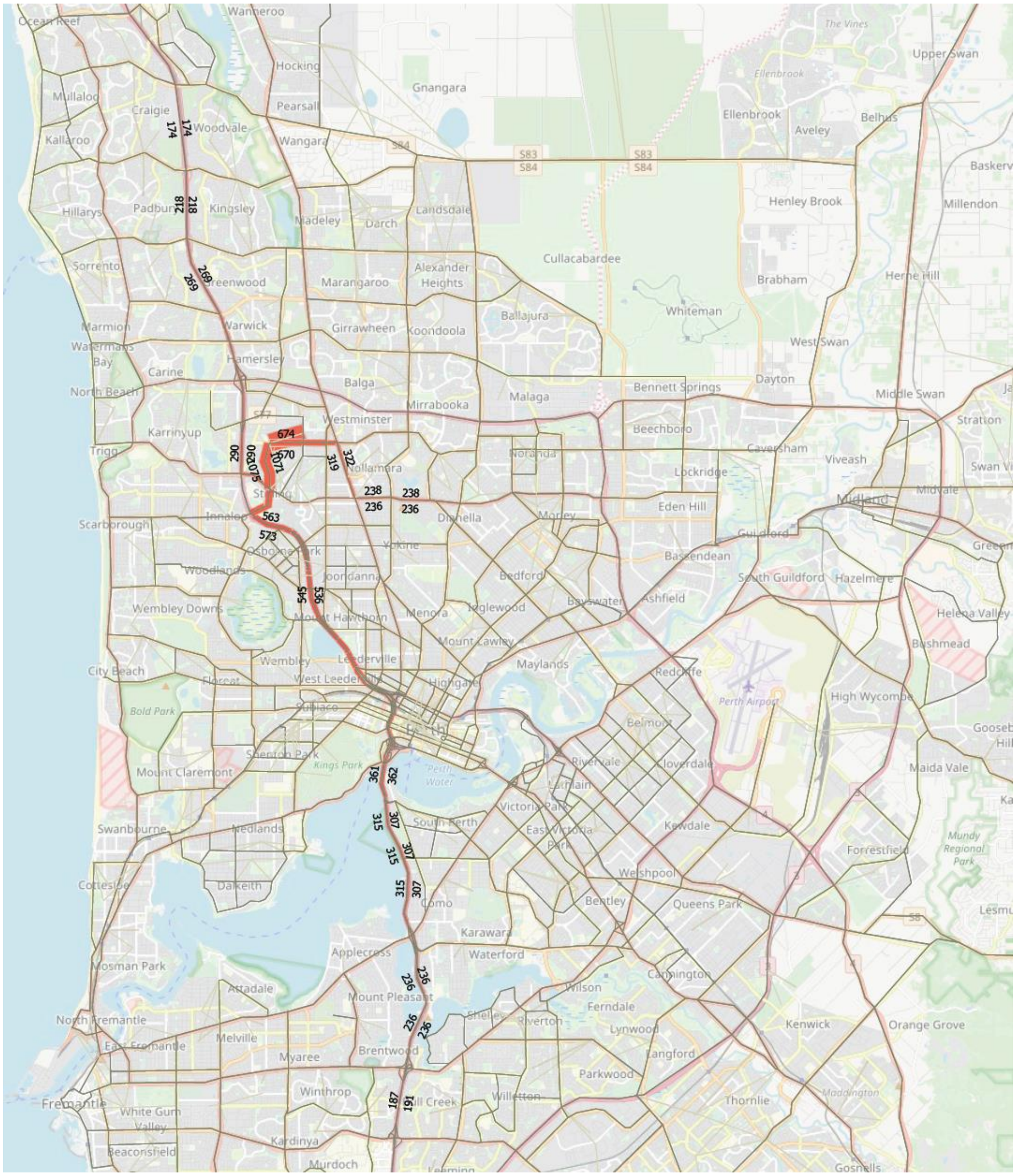


Figure 8.22 contains significantly important information about the distances of travel associated with the work trips attracted by this zone. This figure shows the boundary of the work travel distances onto this zone. It is evident from Figure 8.22 that the longest travel distance for work commuters into zone 100084 is from Bull Creek area to the south and Craigie area to the north. Figure 8.22 also shows the routes which have been chosen by the commuters to work. Accordingly, the most attractive travel routes into zone 100084 are from Kwinana Freeway to the south, Mitchell Freeway to the north and Morley Drive to the east.

As the boundaries of the attractions to zone 100084 have been established, it is now time to analyse the trip length. In order to find the trip lengths, a hypothetical circle is drawn, with the centre of the map chosen to be on zone 100084 (Balcatta area) via Nearmap. This hypothetical circle covers the area bounded by the incoming traffic (as shown in Figure 8.23).

Figure 8.23: Trip length coverage for the attracted traffic to zone 100084

The hypothetical circle shown in Figure 8.23 covers the boundaries of the areas commuted by the work trip travellers associated with zone 100084. According to Figure 8.23, the radius of the circle is 20 km. This means that more than 50% of the work commuters to zone 100084 prefer to travel to this zone for work within a maximum distance of 20 km.

8.2.2 Analysis of the selected samples to the south of Swan River (southern suburbs)

Two samples have been selected from the southern suburbs. Consideration in choosing the samples has been given to the density of the non-residential zones with higher demand for work trips. The focus of this methodology is to assess the trip lengths and not the number of trips attracted to each zone.

Maddington – Orange Grove – Martin (Non-residential zone number 100136)

The Select Link analysis procedure outlined earlier is provided in detail for zone 100136 which is as follows:

- All the zone connectors in and out of this zone have been chosen and an attribute of ul1=1 assigned to them (as shown in Figure 8.24).

Figure 8.25 contains significantly important information about the distances of travel associated with the work trips attracted by this zone. This figure shows the boundary of the work travel distances onto this zone. It is evident from Figure 8.25 that the longest travel distance for work commuters into zone 100136 is from Southern River area to the south and south-west, and Maylands area to the north. Figure 8.25 also shows the routes which have been chosen by the commuters to work. Accordingly, the most attractive routes of travel into zone 100136 are from Tonkin Highway and Kelvin Road to the north, Olga Road to the south and Roe Highway and Albany Highway to the west.

The Select Link analysis for this zone was then run in EMME prompt, following modules 5.11 and 5.21. The result of the Select Link analysis for work trips into this zone is shown in Figure 8.25.

Figure 8.24: Zone connectors for zone number 100136

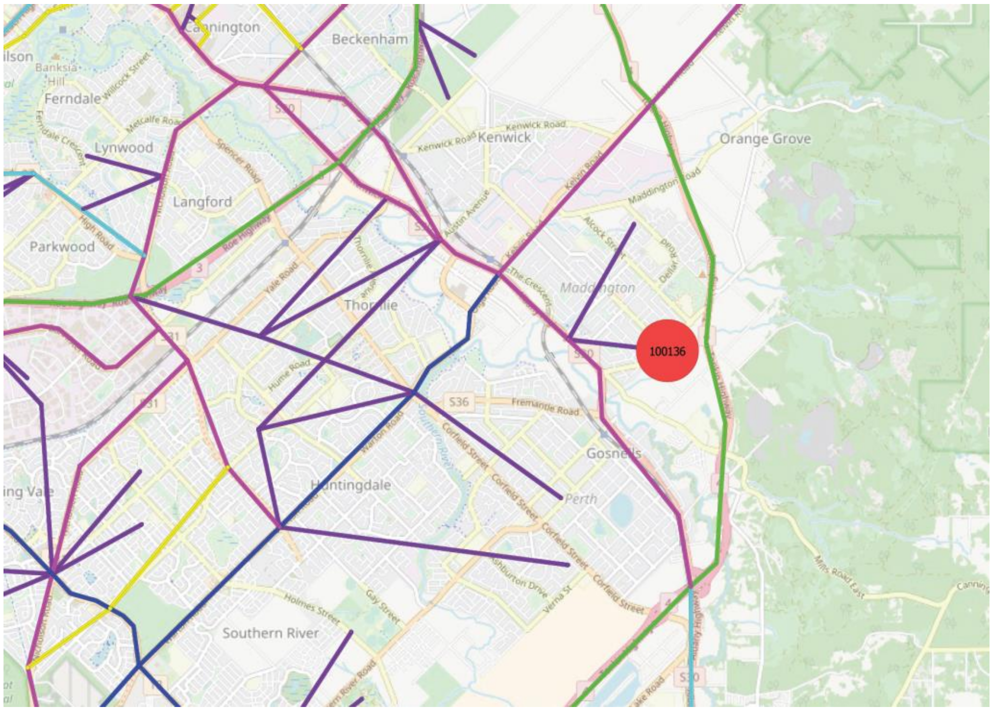
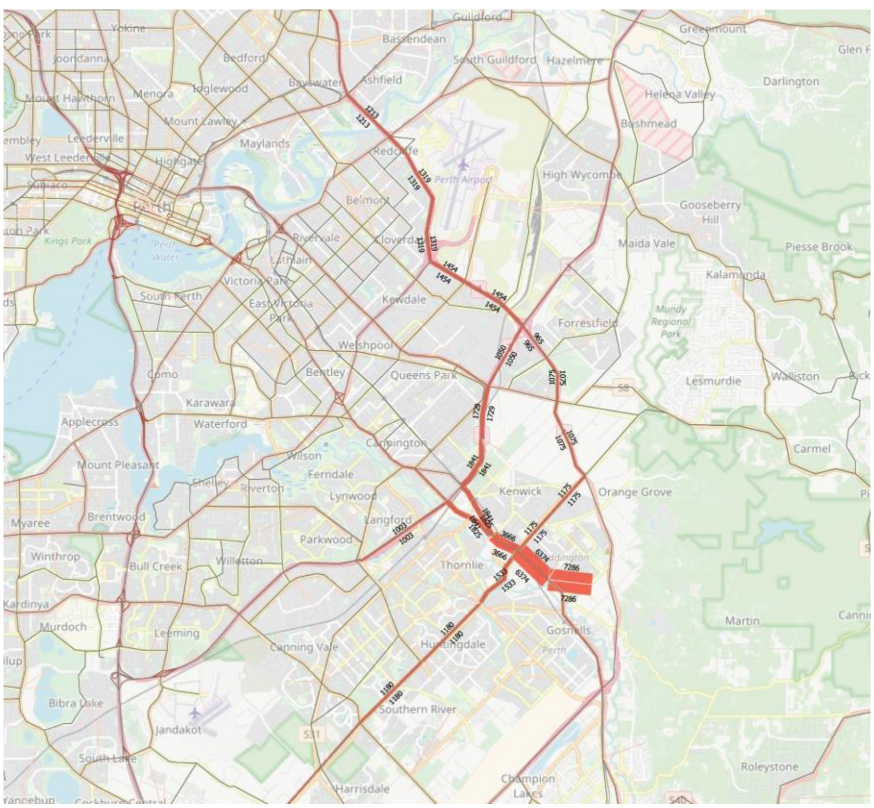


Figure 8.25: Select Link analysis results for zone 100136



As the boundaries of the attractions to zone 100136 have been established, it is now time to analyse the trip length. In order to find the trip lengths, a hypothetical circle is drawn, with the centre of the map chosen to be on zone 100136 (Maddington area) via Nearmap. This hypothetical circle covers the area bounded by the incoming traffic (as shown in Figure 8.26).

The hypothetical circle shown in Figure 8.26 covers the boundaries of the areas commuted by the work trip travellers associated with zone 100136. According to Figure 8.26, the radius of the circle is 15.7 km. This means that more than 50% of the work commuters to zone 100136 prefer to travel to this zone for work within a maximum distance of 15.7 km.

Figure 8.26: Trip length coverage for the attracted traffic to zone 100136

South Lake – Cockburn Central (non-residential zone number 100159)

The Select Link analysis procedure outlined earlier is provided in detail for zone 100159, which is as follows:

- All the zone connectors in and out of this zone have been chosen and an attribute of ul1=1 assigned to them (as shown in Figure 8.27).

The Select Link analysis for this zone was then run in EMME prompt, following modules 5.11 and 5.21. The result of the Select Link analysis for work trips into this zone is shown in Figure 8.28.

Figure 8.28 contains significantly important information about the distances of travel associated with the work trips attracted by this zone. This figure shows the boundary of the work travel distances onto this zone. It is evident from Figure 8.28 that the longest travel distance for work commuters into zone 100159 is from Success area to the south and Waterford area to the north. Figure 8.28 also shows the routes which have been chosen by the commuters to work. Accordingly, the most attractive routes of travel into zone 100159 are from Kwinana Freeway to the north and south.

Figure 8.27: Zone connectors for zone number 100159

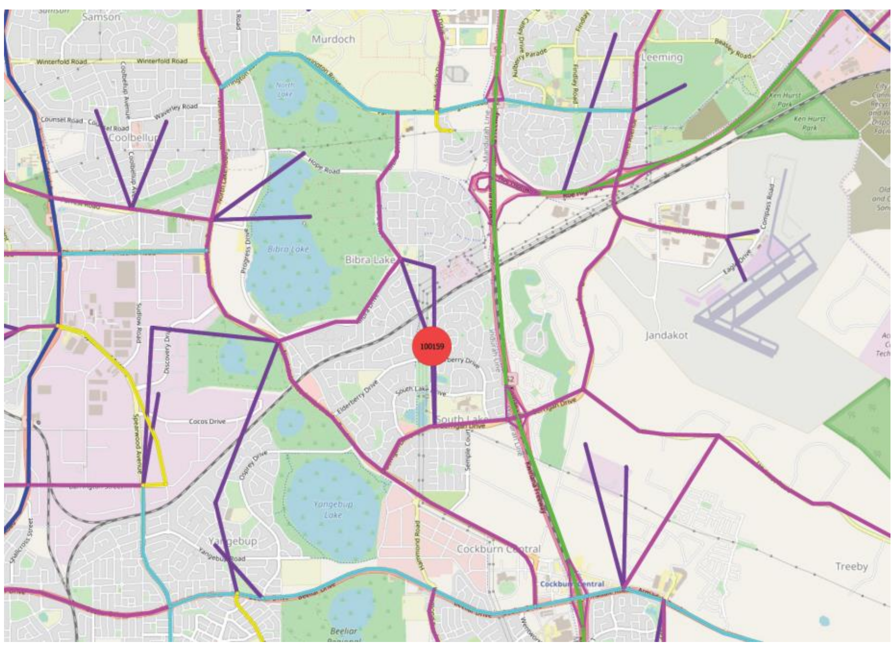
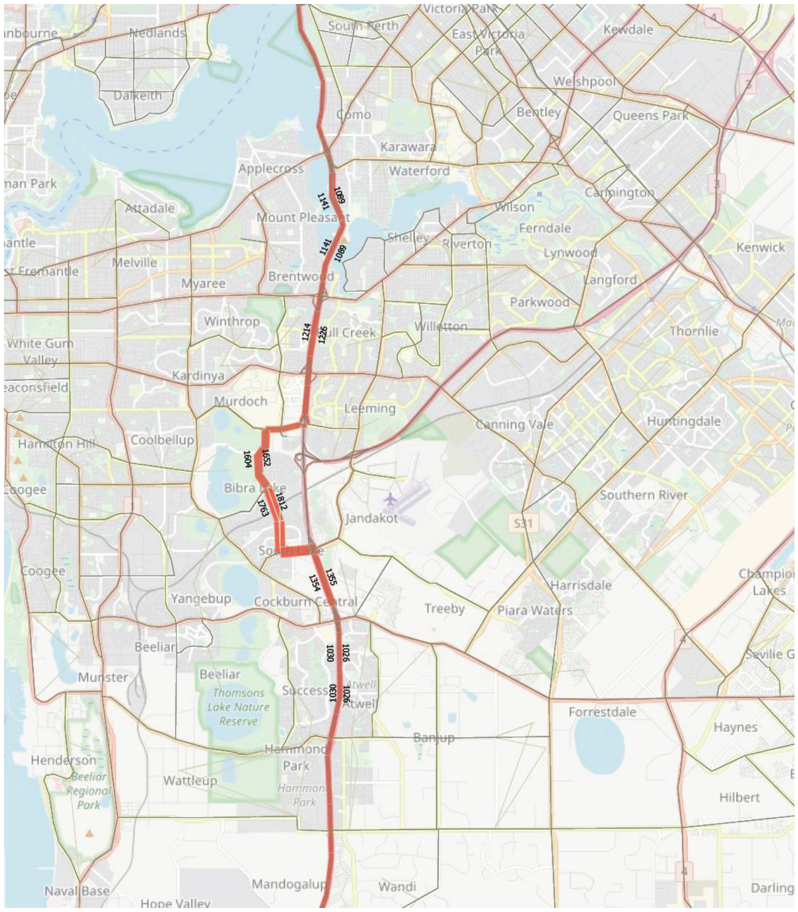


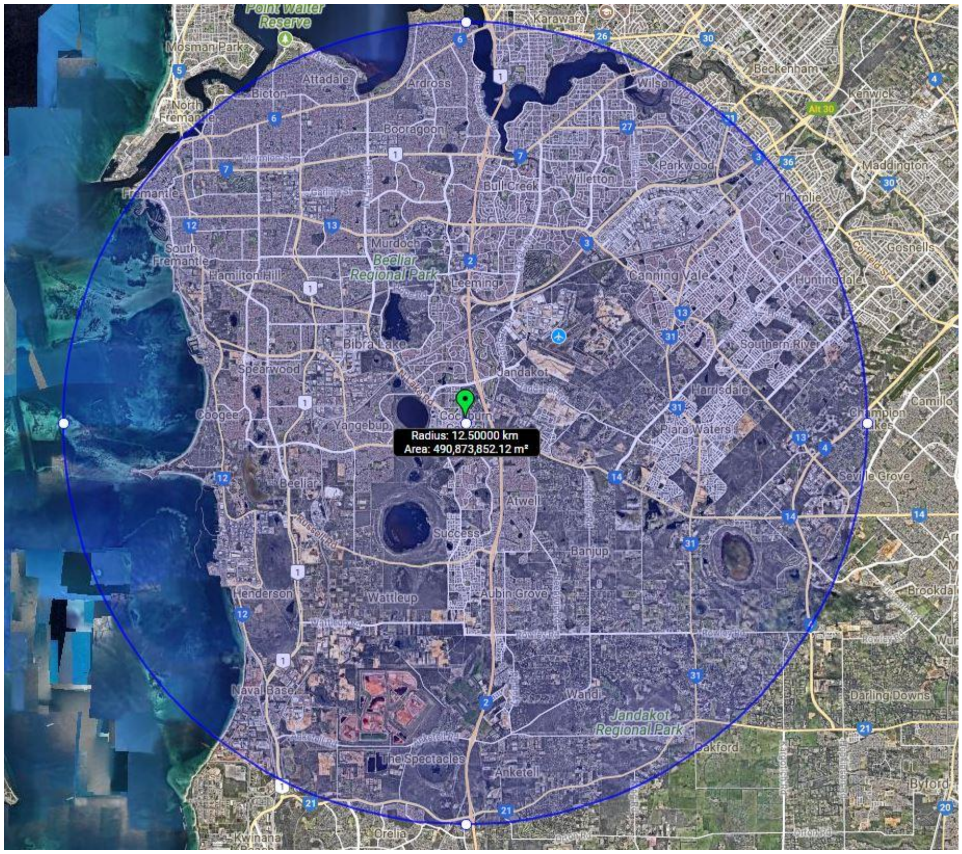
Figure 8.28: Select Link analysis results for zone 100159



As the boundaries of the attractions to zone 100084 have been established, it is now time to analyse the trip length. In order to find the trip lengths, a hypothetical circle is drawn within the centre of the map chosen to be on zone 100084 (Maddington area) via Nearmap. This hypothetical circle covers the area bounded by the incoming traffic (as shown in Figure 8.29).

The hypothetical circle shown in Figure 8.29 covers the boundaries of the areas commuted by the work trips travellers associated with zone 100159. According to Figure 8.29, the radius of the circle is 12.5 km. This means that more than 50% of the work commuters to zone 100159 prefer to travel to this zone for work within a maximum distance of 12.5 km.

Figure 8.29: Trip-length coverage for the attracted traffic to zone 100159



A brief review of the trip-length investigations as per Methodology 2 outlined in this chapter is provided in Table 8.4.

Table 8.4: Brief review of the trip-length investigation on four samples

Sample zone ID - Suburb detail (Traffic zone)	Maximum trip length (Km)
Sample 1 - Malaga (100063)	7.0
Sample 2 - Balcatta - Hamersley (100084)	20.0
Sample 3 - Maddington - Orange Grove – Martin (100136)	15.7
Sample 4 - South Lake - Cockburn Central (100159)	12.5

As discussed in Chapter 5, and through a number of analyses undertaken on the actual work-trip data provided by the DoPLH, it was established that most of the work trips in the Perth metropolitan area occur at a distance of 10 to 20 km, with the actual average trip length estimated to be 15.4 km. As can be seen in Table 8.4, for the selected four samples from different areas within the metropolitan area, the maximum modelled trip length is within the estimated range of 7 to 20 km. This can again confirm the accuracy of the trip-length calibration of the model and further the accuracy of the Gamma function introduced to the Gravity Model for distribution.

The analysis of the trip length outlined in section 8.6 once more confirms the self-sufficiency of the model in terms of distributing the work trips between the OD zones.

8.3 Summary

This chapter focused on reviewing the application of trip-distribution calibration on a smaller scale. Two separate and standalone methodologies were provided, of which the first was the assessments of the Desire Lines and the second was through Select Link analysis.

In methodology 1, a review of the results of the number of work trips generated by 10 different samples of residential zones (five from the northern suburbs and five from the southern suburbs) suggested that the number of modelled work trips is in agreement with the actual work trips provided by the DoPLH. A number of different plots were provided to relate the modelled work trips to the actual work trips, and the results of the analysis confirm the accuracy of the modelled trip distribution and hence the accuracy of the deterrence function.

In methodology 2, two different non-residential sample zones from the northern suburbs and two different non-residential sample zones from the southern suburbs were selected and the model output for the maximum trip length for the four samples was undertaken. According to the results of the trip-length assessments, it was established that the maximum trip length modelled for the samples are within the acceptable, actual trip length estimated in Chapter 5.

The outcome of both methodologies confirms the accuracy of the deterrence function established for the work trips in the Perth metropolitan area and leads to a successful trip distribution at a smaller scale. Therefore, the objectives of this chapter have been achieved.

9 WORK TRIPS CROSSING SWAN RIVER

So far it has been established that the developed EMME model for the Perth metropolitan area and Peel region can be calibrated for the work trips and can replicate the distribution of the work trips in accordance with the actual observed trip distributions between ODs.

Now that the model has been calibrated, different studies and investigations on work trips can be undertaken, and the outcome of the assessments are considered to be reliable because the model is deemed to be able to reflect the actual travel pattern for work trips.

One of the important investigations normally conducted for major cities like Perth, with a river crossing the city and dividing it into two sections, is to estimate the contribution of the traffic on different means of connections between the two parcels of the city (north and south of the river).

The connections between the two sections of Perth are provided via a number of bridges. Having an accurate sense of the traffic on the bridges can assist with different planning and infrastructure provisions.

In this chapter, a review of the existing bridges in Perth will be provided. Then, through undertaking different analyses in the EMME model, the percentages of work trips crossing each bridge to access the other side of the river for work will be assessed. It is noted that the Perth CBD, which is one of the major attractions for daily work trips, is located to the north of the river. Accordingly, heavy traffic for work is anticipated to occur from the south of the river towards the CBD, and as such the bridges will need to cater for this high demand.

9.1 Existing Bridges on Swan River

There are currently eight major bridges on the Swan River which connect the southern section of the river to its north, as shown and explained below:

1- Fremantle Traffic Bridge, which connects Fremantle area to North Fremantle area via Queen Victoria Street.

2- Stirling Bridge, which connects Fremantle area to East Fremantle area via Stirling Highway.

3- Narrows Bridge, which connects the City of Perth to South Perth area via Mitchell Freeway. Note: the extension of Mitchell Freeway towards the south is called Kwinana Freeway.

4- The Causeway, two bridges which connect Victoria Park area to East Perth area.

5- Windan Bridge, which connects Burswood area to Northbridge area via Graham Farmer Freeway.

6- Garratt Road Bridge, which connects Bayswater area to Ascot area via Garratt Road.

7- Redcliffe Bridge, which connects Bayswater area to Redcliffe area via Tonkin Highway.

8- Bassendean Bridge, which connects Bassendean area to Guildford area via Guildford Road.

A hierarchy of the bridges in terms of the average weekday traffic volumes is shown in a descending format in Table 9.1. This table also shows the year in which the traffic count was sourced, the number of lanes and the speed limit on each bridge. All the above-mentioned bridges are also shown graphically in Figure 9.1. It is noted that the historical traffic-count data in Table 9.1 was obtained from the Main Roads Western Australia (MRWA) website (2017).

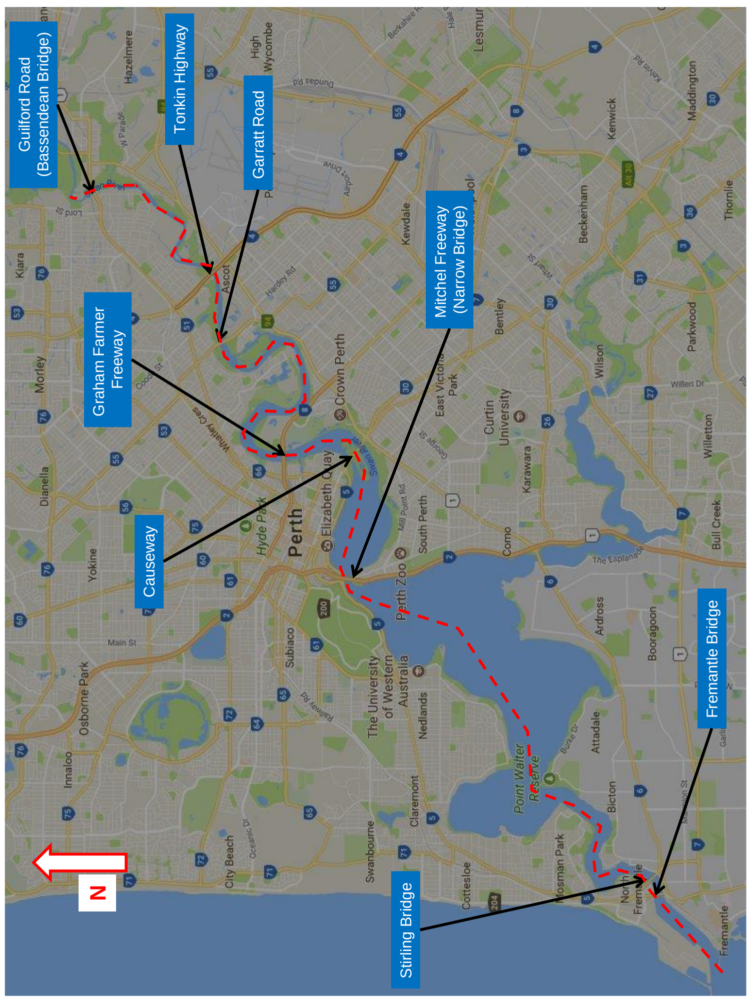
The red-dotted line shown in Figure 9.1 crosses the bridges and shows the detail of the author’s traffic analysis.

Table 9.1: Details of Perth bridges crossing Swan River

Number	Bridge Name	Average Daily Traffic Volumes (Vpd)	Year of the Traffic Count	Total Number of Lanes	Speed (Km/hr)
1	Mitchell Freeway (Narrow Bridge)	174394	2011	10	100
2	Graham Farmer Freeway (Windan Bridge)	88553	2010	6	80
3	Tonkin Highway (Redcliffe Bridge)	51438	2010	6	60
4	Causeway	48832	2014	4	60
5	Stirling Highway (Stirling Bridge)	34988	2011	4	60
6	Guilford Road (Bassendean Bridge)	30401	2012	2	60
7	Fremantle Bridge	24470	2009	4	60
8	Garratt Road Bridge	17257	2012	2	60

Source: Main Roads Western Australia (2017)

Figure 9.1: Location of Perth bridges crossing Swan River



9.2 Select Link Analysis for Bridges

All the associated links on bridges were assigned ul1=1 and a Select Link analysis was conducted for the bridge links as per the procedures outlined in Chapter 8. The difference between the link analysis for bridges and those discussed in Chapter 8 is that when assessing the Origin and Destination (OD) zones, the centroid connectors were assigned a ul1=1 in order to assess the incoming and outgoing traffic to the respective zones. However, when assessing the bridges, the actual bridge links were subject to the Select Link analysis. The matrix used for the Select Link analysis is for work trips only so that the results are only reflective of the work-trip purpose.

The results of the Select Link analysis show the number of work trips which have crossed the bridges towards north and south to access the workplaces. Therefore, a fixed-demand assignment was conducted as per the following modules and commands in EMME:

Note: the selected options are highlighted in red.

2- Run 5.11 to start an assignment

Select: Type of assignment

1= fixed demand traffic assignment

2= fixed demand transit assignment

3= variable demand traffic assignment

4= end

Select option 1 and run a new assignment

Select: 1= single class assignment on auto mode

2= single class assignment with generalized cost

3= multiclass assignment

4= multiclass assignment with generalized cost

5= generalized cost multiclass assignment with class specific volumes

6= generalized cost multiclass assignment with path analysis

Select: Source for additional volumes

1= no additional volumes

2= auto equivalent of transit vehicles

3= user data on links and turns

4= transit vehicles and user data

5= assign additional demand (additional options assignment)

Select number 5 and introduce the input matrix for distribution (matrix of work trips in this instance to account only for work trips).

Select: Source for additional attributes

1= link user data UL1

2= link user data UL2

3= link user data UL3

4= link length

5= none (no additional path attributes calculated)

6= link user data, length or extra link attribute

7= additional attributes on links and turns

Select number 1, as it is assumed that the additional centroid connector attribute to assist with Select Link analysis is UL1.

Enter: Operator to compute additional path attributes=+

Select + to be used as the operator.

Enter: Lower, upper threshold for active paths

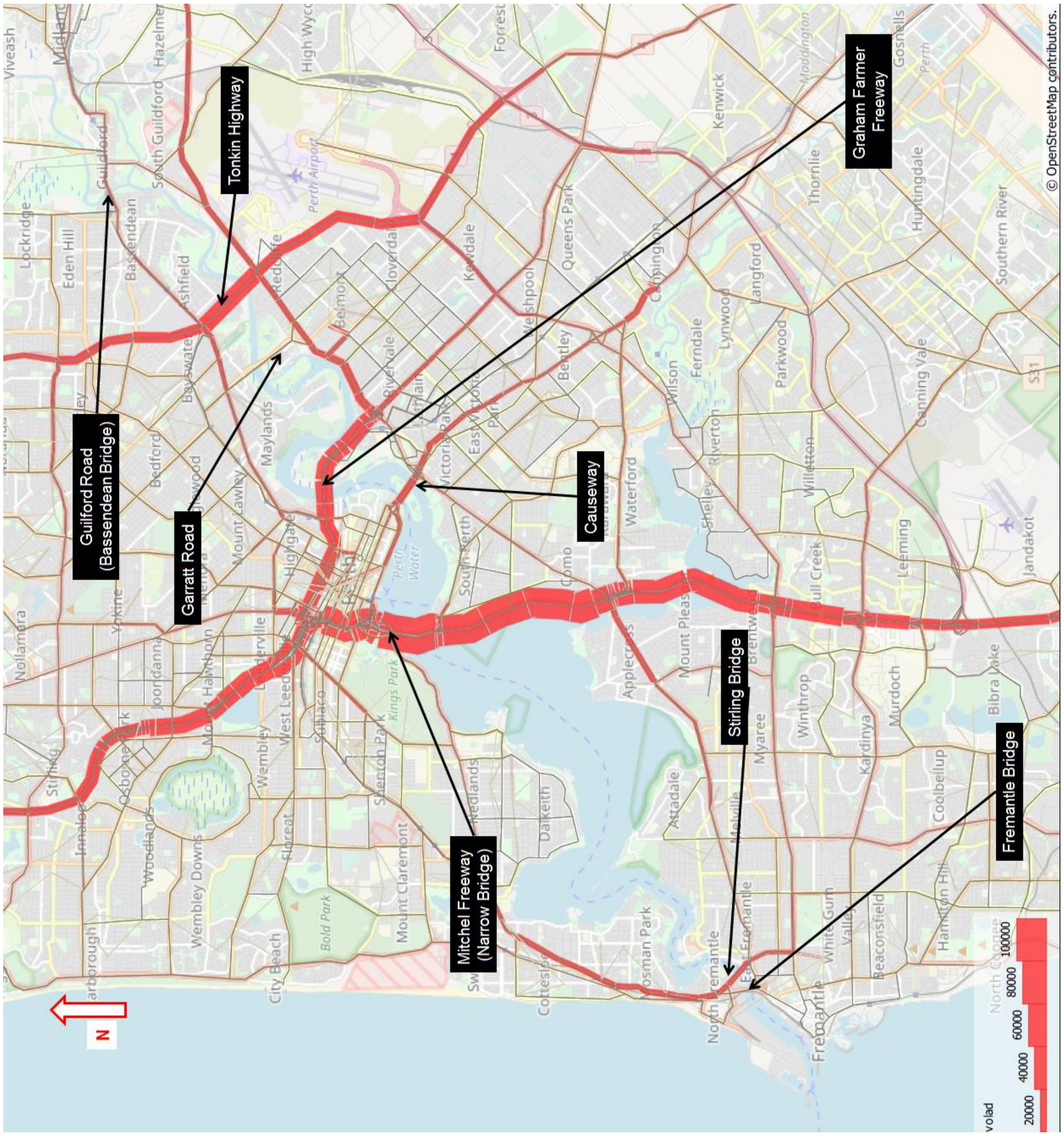
Select 1 to choose the lower threshold for active paths.

Now it is time to run 5.21.

Once the assignment is concluded, the model shows the traffic volumes on all links within the modelling area. The traffic volumes subject to assessment are for *volad* of the bridge links, which were assigned an additional attribute of UL1.

The result of the Select Link analysis is shown in Figure 9.2. In this figure, the thickness of the lines shows the intensity of the work trips.

Figure 9.2: Select Link analysis for links associated with the eight bridges crossing Swan River



As shown in Figure 9.2, and as was expected, the majority of work trips commuters from the southern suburbs use the Mitchell Freeway to access the CBD and other northern suburbs for work. The thicknesses of the lines also confirm that the hierarchy of the roads in terms of number of lanes and speed is considered in the model, and as such the model is logically distributing the trips on the road network with the aim to minimise the time of travel for work trips.

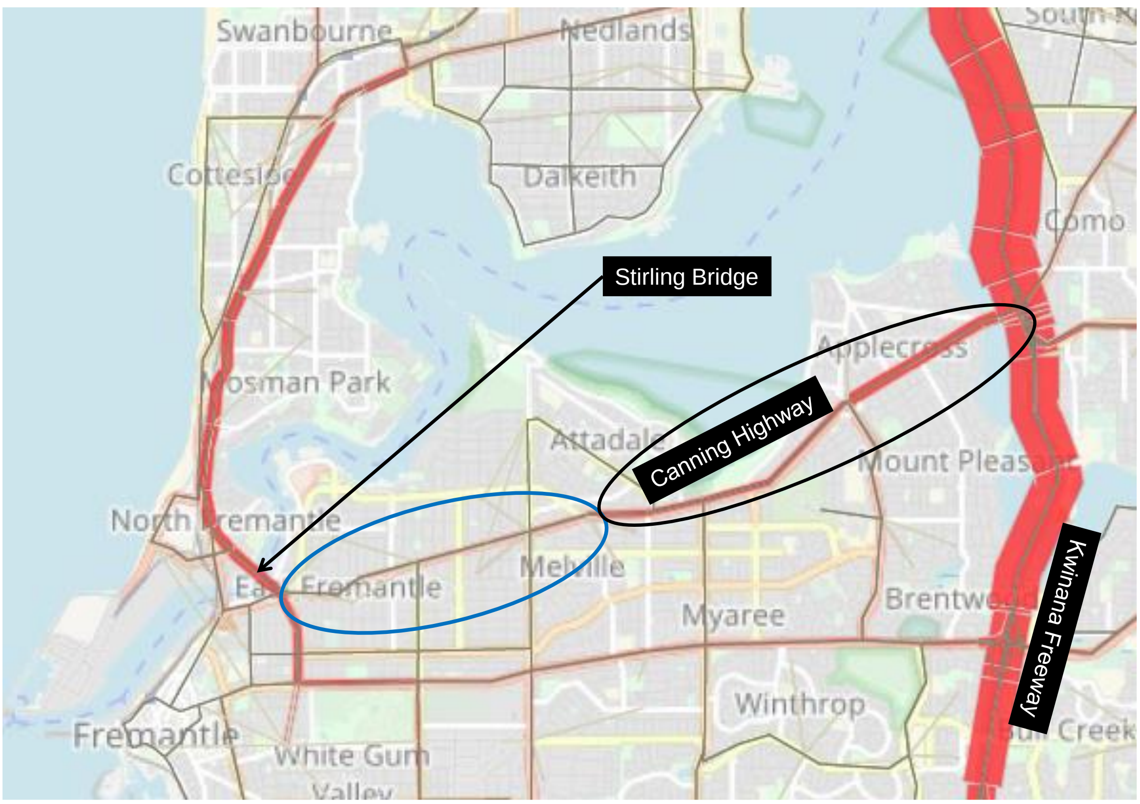
For the sake of argument, let us focus on Mitchell Freeway – Kwinana Freeway from the south towards the Swan River and further towards the Perth CBD.

As can be seen in Figure 9.3, work trips of commuters residing in the southern suburbs are attracted from different locations towards the Kwinana Freeway via the local roads coded in the model. This figure shows that the work trips are cumulatively added onto Kwinana Freeway from south towards the north as the thickness of the line gradually increases.

Figure 9.3: Kwinana Freeway

Figure 9.4 shows an extraction of the Select Link analysis result on Canning Highway between Kwinana Freeway and Stirling Highway. As shown in Figure 9.4, the work trip-makers residing within the areas shown in the black circle prefer to travel towards east on Canning Highway and access the Kwinana Freeway to travel towards north of the river. However, residents within the blue circle prefer to drive towards west on Canning Highway and access Stirling Highway to travel towards the north of the river.

Figure 9.4: Canning Highway between Kwinana Freeway and Stirling Highway



These are just a few samples of numerous analyses which can be made when you have a calibrated model for distribution. The developed model for the Perth metropolitan area is calibrated for work trips through assessments of actual data provided by the DoPLH. The results shown in different formats of plots, figures and tables can only be referred to as reliable when one can show that the calibration of distribution is justified, which has clearly been shown in this thesis through a number of analyses.

9.3 Percentage of Work Trips on each Bridge

The results of the work trips on each bridge were extracted from the EMME model (volad of work trips on bridges) and imported into Microsoft Excel in order to establish the percentages of work trips on different bridges. The result of the analysis is shown in Table 9.2.

Table 9.2: Percentage of work trips

Number	Bridge Name	Estimated Percentage of Work Trips
1	Mitchell Freeway (Narrow Bridge)	38.9%
2	Graham Farmer Freeway (Windan Bridge)	19.6%
3	Tonkin Highway (Redcliffe Bridge)	19.3%
4	Causeway	9.4%
5	Stirling Highway (Stirling Bridge)	6.8%
6	Guilford Road (Bassendean Bridge)	3.3%
7	Garratt Road Bridge	1.7%
8	Fremantle Bridge	1.0%

Table 9.2 demonstrates that 38.9% of daily work trips which require the work trip-makers to cross Swan River to either travel towards north or south occur via the Narrows Bridge. The rest of the travel routes have also captured portions of work trips in accordance with their hierarchical orders, which once more confirms the model's performance. The only mismatching outcome of the hierarchical order is for Fremantle Traffic Bridge and Garratt Road Bridge. To address this mismatching, it can be said firstly that the percentages are quite similar and the difference is only 0.7%. More importantly, it can be concluded from the model that Stirling Highway, which is in close proximity to Fremantle Traffic Bridge, has been chosen as a more attractive route to service the work commuters.

9.4 Summary

As established in previous chapters, a significantly valuable outcome of this thesis is that the strategic daily transport model developed is considered to be well-calibrated for work trips. Accordingly, it is valid to use this model for many different work-trip analyses. One of the possible forms of analysis for cities which have been divided into two parts because of the existence of a river is a river crossing assessment. A river crossing assessment was undertaken as part of the objectives of this chapter to investigate the percentage of work trips by different means of connections (bridges) on the Swan River.

10 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

This thesis has been prepared for submission and assessment for a Doctor of Philosophy degree in Civil Engineering, with Curtin University in 2017.

Trip distribution is the second step in the traditional Four-Step Modelling (FSM) process, which aims to distribute traffic between the production and attraction zones. The errors which occurred during the trip-distribution step will propagate throughout the model and will result in inaccuracy of the outcome of the modelling. The significance of trip distribution has been reviewed, and for years by different researchers in the area of traffic and transportation engineering. The use of synthetic models in undertaking the trip-distribution step has been a popular area for research, and the Gravity Model is the most common synthetic method for trip distribution. The Gravity Model in trip distribution accounts for people's actual intentions for travelling within the modelling area by considering the impediments of travel such as time, distance or cost of the journey. A comprehensive literature review was undertaken and documented in this thesis, which confirms the significance of trip distribution and the application of the Gravity Model for trip distribution. The concept of deterrence function has been introduced into the Gravity Model to assist with replicating people's actual travel patterns. For years, different functions have been suggested for use for deterrence function, of which three are most commonly in use – Exponential function, Power function and Gamma function.

The main objective of this research was to calibrate a distance-deterrence function for work-trip length in the Perth metropolitan area and Peel region. Therefore, the latest available (actual) travel survey data for work trips in Perth was obtained and a number of different and complex analyses were conducted on it. The obtained actual travel survey data relates the number of work trips to the distances of travel (trip length). In order to establish a distance-deterrence function for work trips in Perth, all three different above-mentioned functions were employed and curve-fitting match assessments undertaken to find the most appropriate function for the actual surveyed work-trips data for the Perth metropolitan area and Peel region. According to the results of the analysis, it was determined that a Gamma function with appropriate constant coefficients results in the best curve-fitting match to the actual travel survey data, as seen in the following equation:

$$Fij = 2742.519 * (dij)^{1.678} * e^{-0.160}$$

Therefore, this Gamma function is recommended to calibrate the work-trip length data in the Perth metropolitan area and Peel region. Several different analyses in the form of plots and graphs were also conducted to assess the results of the Gamma function against the actual work-trip length data provided by the DoPLH.

As part of the other objective of this research, and primarily to assess the performance of the proposed Gamma function for the work-trip length calibration, a strategic transportation model was developed for the entire Perth metropolitan area plus a portion of the Peel region in Western Australia. The transport model was developed with respect to the land-use data provided by a number Australian governmental agencies, and the model was established in consideration of the traditional FSM process. Trip generation was estimated from the provided land-use data. The trip-distribution step was based on the Gravity Model, and in consideration of the developed Gamma function, the Mode Choice step was not included in the modelling process. The trip Assignment step was based on equilibrium equations using EMME 4 software.

The transportation model was established for the Base Year (Year 2011), as the household data information was for this year. The FSM model calibration was based on the targeted actual traffic count information on the major regional roads for the Base Year.

The performance of the proposed and recommended Gamma function for work trips was reviewed on both strategic and smaller scales. The results of the modelling area were assessed through different methodologies:

1- The results of the modelled work-trips data were plotted against the actual work-trips data provided by the DoPLH, and it was established that the data follows a linear trend line with a Square Root of 0.893, which shows a perfect result at a strategic level.

2- Ten residential zones (traffic production zones) were selected, and the total work trips outgoing from them onto the attraction zones were reviewed in detail. As a result, the actual number of work trips from all 10 zones were compared with the outcomes of the modelling, and it was established that the model trip distribution works perfectly in line with the actual Origin and Destination data.

3- For the 10 residential zone samples, the modelled Desire Lines were plotted, and it was established that the model does not distribute the traffic in an unrealistic manner and towards unnecessarily far distances. Hence the self-sufficiency of the modelling was also compared with the actual trip-length data.

4- Select Link analyses were also undertaken to analyse the trip-length calibration of the modelled work trips. According to the results of the Select Link analysis for four different non-residential traffic (attraction) zones, it was established that the model distributes 50% to 100% of the trips close to the estimated average trip length for the Perth metropolitan region.

Finally, and when the work-trip distribution calibration of the developed EMME model was ascertained, an important assessment of work trips was also conducted to estimate the river crossing work-trip volumes through Select Link analysis. As part of this assessment, the percentages of daily work trips which have used different bridges to cross the Swan River were established.

10.2 Recommendations

As a result of executing this study, the following recommendations are made:

1. This thesis concludes and recommends that the outlined Gamma functions reported in this thesis would be able to calibrate the trip lengths for work trips.
2. The outcome of this research is a calibrated transportation model for work trips based on the actual travel survey results for the Base Year (Year 2011).
3. A number of different and significantly important analyses of the work trips for work trip-makers in the Perth metropolitan region can be undertaken through a review of the outcome of this research, and in particular the developed EMME model.
4. Should the EMME model developed as part of this research be further fine-tuned, it can be used as a base for future traffic forecasting based on future population growth and future infrastructure changes.
5. The EMME model developed as part of this research can be used for sub-area modelling purposes.
6. The EMME model developed as part of this research can be used by governmental agencies and the private sector.
7. The EMME model developed as part of this research is based on daily traffic volumes and can be altered to model peak-hour situations also.
8. The structure and methodology used for this research can serve as a guide for the transportation modeller to calibrate trip distribution and therefore develop independent models and undertake the same analyses to ascertain the performance of the trip distribution.
9. As it is assumed that work travel patterns do not differ significantly in other cities in Australia, the outcome of this research can also be used as **initial guidance** for calibrating the work-trip distribution in those cities.

10.3 Future Research

The research and investigation in science is endless. To continue this area of research, future students and researchers are encouraged to focus on other trip purposes and try to investigate the deterrence functions for those trips. This author also recommends future students and researchers to work on hourly travel demand and transportation modelling. They can use the information contained in this research as a guide to continue this work.

Due to the limited time and lack of access to government multimodal transport models in Perth, this methodology was applied to a simple independent transport model developed by the author; however, it is suggested that the methodology outlined in this thesis be applied in a more sophisticated multimodal transport model to assess the impact of the suggested deterrence function for work trips.

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Appendixes

Appendix A1

A Critical Review of Current Transport Models

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ABSTRACT

A comprehensive review of the available literatures was presented in this Chapter. The focus of the literature review was to establish the importance of trip distribution and Transportation Modelling (in particular) so that the significance of the current research objectives is further confirmed.

KEYWORDS: Traffic models; literature review

INTRODUCTION

Travel demand forecasting, short term and long term transportation modelling can be considered as an indispensable area for research and this is due to the fact that for a developing area such as Perth metropolitan regions the government policies are towards increasing the population which results to a huge requirement for accurate traffic projection and robust transportation planning and future road provisions Rong, Ming and Chonyu (2012) [1] state that there are two major approaches for the demand forecasting, the first one is the common Four Step Modelling (FSM). FSM approach has been used for many years by vast majority of the researchers and its uses are mainly for large scale; strategic transport modelling. The second approach is known as the activity based or micro simulation method which deals with the travel demand in finer and smaller scales.

The use of four step modelling (FSM) has always been a very interesting research area for traffic and transportation engineers. McNally (2007) [2] has undertaken a comprehensive study on the concept of FSM, its input, output and the probable restrictions and problems.

LITERATURE REVIEW

- The first step in FSM is the trip generation which measures the total number of originated trips in the area which is intended for study/modelling. Trip generation can be defined as a process of estimating the total number of trips generated from a particular traffic zone. Estimating the trip generation for a specific area under study is a complicated process but it can be practically undertaken by measuring the number of trips coming into and leaving that zone over a specific period of time, 'eg' 24 hours. This practice provides an accurate estimation of the trip generation for that traffic zone. Wu and Liu (2014) [3] research provides a comprehensive overview on different data collection methods from the conventional fixed point sensors to the more recently introduced high-resolution event based data. Although these exercises result into an accurate estimation of the trip generation but it is considered as an expensive practice which is not feasible for traffic zones with larger scales. Therefore other policies and guidelines are commonly being used to estimate the trip generation. Some of these common guidelines can be found in (Mousavi, Bunker and Lee 2012) [4] published journal.

- Trip distribution is known as the second step in FSM. The distribution of trips between traffic zones can be demonstrated by an Origin and destination (OD) matrix Trip distribution follows the trip generation and distributes different generated trips from the generation zones onto attraction zones. This research mainly focuses on trip distribution step out of all four steps in FSM.

- Mode choice can be defined as the intention of travelers in choosing their mode of transport for their trips. Mode choice is highly dependent on a traveller's personal intentions. Examples of modes of transport include walking, bicycling or driving any type of motorised vehicle, or choosing public transport for travelling from one zone to another zone. Ashlatha, Manju and Zacharia (2013) [5] describe the mode choice step as a process of a specific mode of transport under a set of circumstances. They have modelled and analysed the mode choice behaviour of commuters in a case study; Thiruvananthapuram in India.

- The route choice or assignment stage is the fourth step in FSM. In this step, all of the distributed traffic between the generation and distribution zones is assigned to the existing road network, such as highways, freeways and roads within the locality of the area intended for modelling. Yousefi, Abbasi & Anvari (2014) [6] state that finding the optimal routes to reach the destination is considered as a significant challenge for Intelligent Transportation System (ITS). They have proposed a mechanism which includes two phases to investigate the optimal rout choice. An Origin and destination (OD) matrix Trip distribution was suggested by Rasouli (2014) [7].

DEFINITION

Yanli et al., (2013) [8], in their paper share the disadvantages of the existing urban transportation models in China and suggests a framework to establish an integrated multi-modal Transportation Model which follows the traditional FSM. It is recommended that an integrated model should be established for the urban areas in China in accordance with the application of FSM so that it can be used for the planning prospective for the urban areas.

GRAVITY MODEL

The Gravity Model which was first introduced by Mc Donalds and Blunden in 1968 is the most well-known synthetic model in estimating the trip distribution and is widely used in the transportation engineering which is actually based on Newton's concept of gravity (Erlander and Stewart (1990) [9]).

$$Tij = Pi * \frac{Aj\ Fij\ Kij}{(\sum_{j=1}^{n}(Aj\ Fij\ Kij))} \quad (1)$$

T_{ij}= Number of trips from zone i to zone j;

P_i= Number of trip production in zone i;

A_j= Number of trip attraction in zone j;

F_{ij}= Friction or balancing Factor (represents the spatial separation between zone i and j);

K_{ij}= Optional adjustment factor, recommended to be 1.

Equation 1 is considered as the basis in most of the transport engineering studies to determine the trip distribution between the zones in the area of the modelling. Therefore, the technique used in this research to estimate the trip distribution is upon Gravity Model.

IMPACT DISTANCE IN GRAVITY MODEL

Finding a way to introduce the impact of distance into the gravity transport model has been a common area of research in recent years. It is evident that travelers prefer to travel to closer destinations for different trip purposes such as work, education or shopping. Various researches have been undertaken in recent years to investigate traveler behaviour, especially in terms of specific travel purposes such as work, education and shopping.

Based on the data sourced from the Office for National Statistics (UK), in 2011 the average distance commuted to work in London was around 11km while in Wales in the same year it was about 15 km. As a general guide, workers would prefer to find accommodation as close as possible to their workplaces, and would be very reluctant to find a place to live that is far from their workplaces. Day, Habib and Miller (2010) [10] undertook a research to investigate the impact of the trip timing and duration of the travel for the commuters to work in the Greater Toronto Area (GTA). Their analysis was focused on a typical 3 hours of the morning and afternoon peak period. They also investigated the relationship between the trip timing decision and mode choice of the commuters to work in GTA.

TRAVEL TIME

Mohammad, Chen and Rakha (2014) [11] conducted a research on travel time for a case study along 37-miles freeway section on Hampton Roads Beltway in Virginia. Their analysis was based on the travel time throughout a day between (5am-10pm). They also developed a generic program algorithm to predict the travel time of the future commuters.

For the purpose of an accurate transport modelling and in order to incorporate the impact of distance and time on human travel behaviour, different friction factors have been added to the gravity model over the years.

The gravity model for trip distribution considers some balancing factors (Fij, as pointed in Equation 1) which are known as deterrence functions. Different equations have been studied to estimate the deterrence functions, such as the gamma function, exponential function, power function or a combination of both the power and exponential functions.

Below is a list of the various equations which have been used so far to estimate the deterrence function, as suggested by Ortúzar and Willumsen (1994) [12].

$$Fij = e^{-c(ij)} \quad where\ c > 0 \tag{2}$$

$$Fij = cij^{-b} \quad where\ b > 0 \tag{3}$$

$$Fij = a * cij^{b} * e^{-c(dij)} \quad where\ a, b \& c > 0 \tag{4}$$

In all of the above equations, c_{ij} is an element which directly influences the trip distribution. This factor is known as the generalised cost in the literature, and it can be considered to be distance, time or the combination of time and distance (Mathew and Krishna Rao 2006) [13].

a, b and c are constant numbers which differ from one area to another and are dependent on various factors. It is to be noted that each of these equations might be able to reflect the required deterrence function for modelling, but the challenge is to try and find the most suitable constants (c and/or b and/or a, b and c).

This exercise is known to be the hardest part of the modelling task in traffic and transport engineering and is called the calibration stage. Shrewsbury (2012) [14] describes the calibration of a model as a complex process and suggests that although the analytical methods have been implemented in some modelling packages, the old-fashioned trial-and-error methods are still employed for many other packages. The calibration stage in transport modelling aims to try and find the most suitable parameters to reflect the existing traffic volumes on existing roads in the intended modelling area. This has been undertaken for various modelling project around the world over the years, some of which is briefly described in this Chapter. It is noted that this research aims to investigate the deterrence function using Gamma equation for the Perth Metropolitan Area.

LIMA & ASSOCIATES MODEL

Lima & Associates (2006) [15] developed a travel demand model for the City of Lincoln-Lancaster in the UK, using Trans CAD software. They chose a Gamma function to estimate the friction factor, as shown in Equation 5.

$$Fij = \alpha * I^{\beta} * e^{I*\gamma}\ where\ I\ is\ the\ impedence\ and\ incorporated\ as\ trip\ length \tag{5}$$

After calibrating their transport model, they were able to establish α, β and γ for the City of Lincoln. Their studies covered different trip purposes such as home-based work,home-based shop, home-based recreational and for all other trips which are not generated from homes they have allowed for non home-based trips.

According to their study the following friction factors have been established for the City of Lincoln.

Another example is the research carried out by Evans and Pooler (1987) [16]. The main focus of their study was to investigate the ability of different deterrence functions to replicate the observed patterns of Canadian interprovincial migrations during the period 1961–62 to 1984–85. They employed three different deterrence functions using inverse power, negative exponential and squared distance. The results of each model were analysed and it was established that for their specific modelled area, the power model led to the best possible calibration.

WESTERN AUSTRALIA TRANSPORT MODEL

Across WA, which is the main focus for this research, three major transport models have already been developed and are currently being used for road planning, project evaluation and program planning (Taylor and Scrafton 2003; Department of Planning 2005) [17-18] which are as follows:

The Main Road Western Australia (MRWA) transport model known as ROM (Regional Operational Model).

The Department of Planning (DoP) Strategic Transport Evaluation Model (STEM).

The City of Perth Model (CPM) which is a detailed model for Perth city centre.

Furthermore, a strategic transport model has recently been developed for the City of Mandurah (CoM) by Transcore Pty Ltd (City of Mandurah 2012) [19]. A Gamma function was used to estimate the friction factors.

The coefficients a, b and c in Equation 4 were calibrated for the City of Mandurah and the model was found to be satisfactorily replicate the existing traffic on roads. This study was carried out based on three different trip purposes (work trips, education trips and other trips). The outcome of the model proved that the private car is not the first choice of transport for short distance trips, with other modes like walking or cycling being preferred. It was also established that car trips in the City of Mandurah mostly occur within a distance of 3–5 km (City of Mandurah 2012) [19].

According to New South Wales (NSW) Roads and Maritime website, Roads and Maritime has developed and maintained an EMME transportation model to undertake transport planning and future traffic forecasting. According to this website, the land use data prepared and provided by NSW Bureau of Transport Statistics are fed into the EMME model. The the model consist of major road network and a number of zones to replicate the generator and attractors of the traffic.These strategic models have been calibrated for 7am – 9am during the morning peak hours and 4pm to 6pm during the afternoon peak hour period. The models for AM and PM peak hours have been tried to be calibrated based on the existing traffic volumes on roads.

OTHER STUDIES ON GRAVITY MODEL

Moghazi (2014) [20] developed a calibrated gravity model for the City of Alexandria. They calibrated their gravity model for different trip purposes within the City of Alexandria. The formulation for trip distribution in the model was based on the general assumption that time or distance of the journey is negatively proportional to the trip destination. They subdivided the modelling area into 15 zones. For the purpose of trip generation the data from Census 1996 were used. Calibration of the gravity model was based on the observed trip length for different trip purposes such as work, education shopping and non-home based trips within the City of Alexandria.

Celik (2010) [21] undertook a same research for City of Istanbul. He used the 2006 household travel data for his research. The analysis were conducted for work shopping and non-home based trips and each of the trip purposes in the study area were modelled via exponential and inverse power function and the respective constant coefficients were estimated for each trip purposes.

Thomas and Tutert (2013) [22] undertook research on trip distribution function for the commuters in Netherlands. They used the travel survey data from 1995 and 2004-2008 to evaluate the trip distribution function for their study area. They conducted comparison analysis to investigate the people's travel behaviour for the two periods.

Qi and Ishak (2014) [23] had analysed the travel behaviour over 68 Km corridor of interstate-4 in Orlando, Florida. In their publication, they introduced a stochastic approach for short term travel projection and freeway traffic pattern.

Weifing, Zhengyu and Gaohua (2013) [24] investigated the travel time distribution pattern for four routes of expressways within Shanghai, China. They chose a representative for working day and a typical weekend for their analysis on travel time distribution on their case studies. The outcome of their research proved the best fitting match for the time of travel distribution in the selected expressways.

A comprehensive review on a number of different pre-established short-term traffic forecasting models around the world can be found in (Vlahogianni, Karlaftis and Colia 2014) [25] journal. They have raised 10 challenges for short-term traffic forecasting and reviewed the already established model against these challenges.

In 2001, the University of Connecticut in the United States established a traffic model for the entire University and the surrounding road network using the TModel software. For the purpose of calibrating the model they had undertaken a 24 hour, midweek automatic traffic count for the whole University and the surrounding road network during October and November 1999 when classes were in session. After the establishment and the calibration of the model they used it to forecast the 2004 traffic projections for the University based on the background traffic, the future growth of the surrounding road traffic volumes, and the future growth of the University (University of Connecticut 2001) [26].

TRIP DISTRIBUTION IN GRAVITY MODEL

Grange, Fernandez and Cea (2010) [27] undertook a detailed research on the trip distribution using the gravity model. The trip information they used to estimate the constant coefficients consisted of bus trip data which were collected from a massive survey of Santiago bus users. Their methodology was to employ three different levels of area subdivision corresponding to three different scales as detailed as:

Area subdivision level (1) consisting of 577 zones;

Area subdivision level (2) consisting of 36 districts; and,

Area subdivision level (3) consisting of 7 sectors.

For each of the three subdivisions they were able to find the constant parameters and furthermore they conducted various statistical analysis including r^2correlation between observed and modelled trips, Log-L (Log-likelihood) and Standard Root Mean Square Error (SRMSE) to investigate the goodness and accuracy of their model in relation with the existing data.

Masazumi Ono, (1987) [28], developed a transport model for the Hiroshima urban area using EMME 2 software. The trip distribution her study was based on Gravity Model and the calibration of her model was based upon the targeted existing traffic volumes on roads. As part of her study, she conducted R^2 and RMS assessments for the traffic volumes extracted from the model versus the observed traffic volumes and as a conclusion, she made mentions about the benefits of using EMME model in transportation modelling.

TRANSPORT MODEL FOR DURBAN METRO

Stewart Scott. et al., (2000) [29], developed a strategic transport model for Durban Metropolitan Area. Their main focus was to establish the public transportation within the model and test the accuracy of the transit lines. Accordingly, they gave further consideration on the third step in FSM i.e. Mode Choice. A comprehensive study on the percentages of different transportation modes were conducted in their research. As a conclusion, they state the benefits of EMME software in modelling the public transportation demands. However, they acknowledge the limitation of modelling for other non-private vehicles such as taxis.

TRANSPORT MODEL FOR SALISBURY AREA

In 2009 and to address to the need for a Transportation Model requested by the Wiltshire County Councilor in England, Atkins company developed different models for the Salisbury Area. As a result of the review of the report prepared for this exercise it was understood that three different models were developed for the area of which the public transport model was developed using EMME 3 software. As such a public transport network with transit lines for rail and buses was developed and the assessments of park n ride application were also included in the model. This exercise led into an asset for the Council which was then used for sub-area modelling and analysis.

IMPORTANCE OF CALIBRATION

Yanli Wang, et al., (2017) [30], state the importance of existence of a calibrated model for the purpose of urban redevelopment studies in Metropolitan Areas. The research carried out included assessments of the traffic impacts as a result of the redevelopments in a case study of State of Maryland in US. They had used the pre-established Transportation Model for the State of Maryland to conduct various traffic impact assessments with respect to different redevelopment scenarios. As part of their research process, they also studied the application of FSM for the Transit Oriented Demand (TOD) scenario which was previously introduced to the state wide model. The outcome of the study was a post trip distribution assessments based on different redevelopment scenarios.

BUS RAPID TRANSIT (BRT) MODEL

Tehran, the Capital City of Iran, has always found to have significant traffic issues and the need for auxiliary bus transit routes had been discussed in the past decades. The Bus Rapid Transit (BRT) sysem is now widely implemented in Tehran. As part of the assessments undertaken an EMME model was established for the public transportation and in particular the use of BRT in an INRO conference in 2007. Zakeri Sohi, (2007) [31], undertook an EMME Transportation Modelling for the BRT system in Tehran and compared the daily traffic volume changes as a result of the availability of BRT system.

TRANSPORT PLANNER'S OPINION

Marco te Brommelstroet, et al., (2017) [32], have undertaken an interesting survey (in the form of questioner). Their survey was to establish the respondent's feedback regarding the use of Transportation Models for the purpose of Transportation Planning and decision-making processes. The society of whom the survey was conducted for covered both Transport Planners and Stakeholders. They made an online survey for about 229 respondents primarily working in Germany, Netherlands and Denmark. The result of their survey recommends that most of the Transport Planners do understand the significance of Transportation Modelling; however, they acknowledge the shortcomings of the models, their restrictions and uncertainties. The reason of mentioning this work here is to demonstrate the importance of Transportation Modelling for huge decision-making processes. It can be concluded from this research that Transportation Modelling is widely supported by the planners around the world and in particular as discussed in this paper in European Countries.

OTHER DETERRENCE FUNCTIONS IN USE

Several different and less common deterrence functions are now incorporated into different software packages, which prove the importance of these functions in providing a robust and reliable model in transport engineering. In order to keep the area of research open for further review, some of the functions are briefly introduced and some examples are presented in this document. The Box-Cox and Box-Tuckey functions are mainly used in the VISUM and VISSIM software package (Planung Transport Verkehr, PTV AG 2001) [33]. Ravi et al. (2013) [34] have undertaken a research to investigate delay and fuel loss during the time that vehicles are stopped at intersection for a case study in Ahmedabad city in India. They used VISSIM micro-simulation software to simulate the traffic movement. For the purpose of the calibration a 16 hour traffic count was conducted on a 4 signalised intersections of a busy road within the City of Ahmedabad. Their analysis based on the observed count show that simulation errors resulted from VISSIM software is reasonably low. Siddharth and Ramadurai (2014) [35] undertook a traffic modelling via VISSIM software. Their case study included an area near Tidal park intersection in Chennai, India. After calibrating the model they conducted different sensitivity analysis to investigate the impact of different parameters which affect the driving behavior.

Long-normal and top long-normal are used in the Omni-Trans software package and the Eva model, which uses impedance functions that show significantly higher elasticity (Lohse 2004) [36]. More studies conducted by other researcher in regards to the road engineering (Agrawal, Dikshit, and Ghose 2003; El-Naqa and Abdelghafoor, 2006) [37-38].

It is believed that the examples provided in this section sufficiently show the importance of transportation modelling all around the world and prove the indispensability of such studies and exercises. Considering a rapid growth in population and the area expansion of the Perth Metropolitan Area, travel behavior researches are significantly required for the transportation planning and future infrastructural provisions. Good to be noted that modelling part of this research is currently under review [39].

CONCLUSION AND DISCUSSION

A comprehensive review of the available literatures was presented in this paper. The focus of the literature review was to establish the significance of transportation modelling, trip distribution step of four-step modelling and deterrence functions.

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Editor's note.
This paper may be referred to, in other articles, as:

Ali Rasouli, Dr. Amin Chegenizadeh, and Dr. Hamid Nikraz: "A Critical Review of Current Transport Models" *Electronic Journal of Geotechnical Engineering*, 2017 (22.14), pp 5453-5464. Available at **ejge.com**.

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Appendix A2

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Acceptance Letter

October 27, 2017

Dr. Amin Chegenizadeh
Curtin University
Australia

Herewith, the international scientific committee is happy to inform you that the peer-reviewed draft paper code 17ES100207 entitled (Investigating a Deterrence Function for Work Trips for Perth Metropolitan Area by Ali Raouli, Amin Chegenizadeh, Hamid Nikraz) has been accepted for oral presentation as well as inclusion in the conference proceedings of the ICCESE 2017 : 19th International Conference on Civil, Environmental and Structural Engineering to be held in Barcelona, Spain during October, 30-31, 2017. The high-impact conference papers will also be considered for publication in the special journal issues at http://waset.org/Publications.

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Appendix B

Commercial Land Use Survey Data

FIGURE B1: City of Armadale commercial land use data

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COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m^2 NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1990																
59	ISOLATED USES-OUT SE *	0	0	0	0	280	1,792	0	0	0	0	0	2,072	0	2,072	47
100	SERVICE STATION *	0	0	0	970	410	166	0	0	0	0	0	1,546	0	1,546	24
900	KELMSCOTT CENTRE	0	167	85	896	12,163	3,235	2,216	115	274	0	114	19,265	598	19,863	573
901	CONNELL AVE	0	0	0	0	90	0	0	0	0	0	0	90	0	90	na
902	WESTFIELD	0	0	0	70	2,395	100	250	100	580	0	0	3,495	0	3,495	86
904	ARMSTRONG RD	0	0	0	0	300	0	0	0	0	0	0	300	0	300	na
906	SCHRUTH ST	0	0	0	0	150	0	0	0	0	0	0	150	0	150	na
907	CHALLIS	0	0	0	0	400	0	0	0	0	0	0	400	0	400	na
908	WEST ARMADALE	0	0	0	80	3,834	141	0	0	0	0	0	4,055	55	4,110	92
909	FIFTH RD	0	0	0	0	130	0	0	0	0	0	0	130	50	180	na
910	NARROGIN INN	0	135	0	0	881	0	260	0	0	0	0	1,276	0	1,276	75
911	GWYNNE PARK	0	0	0	70	150	190	0	0	0	0	0	410	0	410	na
913	SEVENTH AVE	0	0	0	0	240	0	0	0	0	0	0	240	0	240	na
914	NICHOLSON RD N	0	0	0	55	155	65	0	0	0	0	0	275	0	275	na
915	ROLEYSTONE	0	0	0	150	2,091	130	380	54	0	0	0	2,805	0	2,805	69
924	BROOKTON HWY	0	0	0	0	243	2	0	0	0	0	0	245	0	245	na
925	ARMADALE T CENTRE	0	190	110	790	32,394	3,422	7,401	3,277	1,751	0	3,034	52,369	2,881	55,250	1,355
926	MOUNTAIN VIEW	0	0	0	0	0	400	0	0	0	0	0	400	0	400	na
927	PEET RD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
928	SOLDIERS RD	0	0	0	0	60	25	230	0	200	0	0	515	0	515	na
929	KELMSCOTT HOTEL	0	0	0	0	846	0	0	0	1,000	0	0	1,846	0	1,846	na
930	ROCK INN TAVERN	0	0	0	0	200	0	0	0	200	0	0	400	0	400	na
931	ARMADALE HIGH SCHOOL	0	0	0	0	80	270	0	0	0	0	0	350	0	350	na
932	RIVER RD	0	0	0	0	410	0	0	0	0	0	0	410	0	410	na
933	FORRESTDALE	0	0	0	0	0	0	0	0	0	0	0	0	90	90	0
934	NICHOLSON RD S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
935	FARM EQUIPMENT	0	0	0	0	0	0	0	200	0	0	0	200	0	200	na
936	TURNER	0	30	0	0	30	0	357	36	0	0	0	453	260	713	24
937	ARMATAGE	0	0	0	0	0	0	0	154	0	0	0	154	0	154	na
938	SECOND ROAD	0	0	0	0	0	0	110	0	375	0	0	485	0	485	na
939	FOURTH ROAD	0	0	0	0	200	600	120	0	0	0	0	920	200	1,120	na
940	JULL ST	0	0	0	0	315	0	35	0	0	0	0	350	0	350	na
941	SEAFORTH AVE	0	0	0	0	0	55	0	0	0	0	0	55	0	55	na
TOTAL		**0**	**522**	**195**	**3,081**	**58,447**	**10,593**	**11,359**	**3,936**	**4,380**	**0**	**3,148**	**95,661**	**4,134**	**99,795**	**2,516**
1993																
59	ISOLATED USES-OUT SE *	0	0	0	0	230	1,792	92	0	0	1,833	0	3,947	130	4,077	153
100	SERVICE STATION *	0	0	0	570	610	146	0	0	0	0	0	1,326	0	1,326	26
900	KELMSCOTT CENTRE	0	0	0	1,016	12,736	2,775	2,157	97	674	0	114	19,569	1,088	20,657	550
901	CONNELL AVE	0	0	0	0	90	0	0	0	0	0	0	90	0	90	na
902	WESTFIELD	0	0	0	70	2,395	100	250	100	580	0	0	3,495	0	3,495	74
904	ARMSTRONG RD	0	0	0	0	300	0	0	0	0	0	0	300	0	300	na
906	SCHRUTH ST	0	0	0	0	150	0	0	0	0	0	0	150	0	150	na
907	CHALLIS	0	0	0	0	400	0	0	0	0	0	0	400	0	400	na
908	WEST ARMADALE	0	0	0	80	3,834	141	0	0	0	0	0	4,055	55	4,110	57
909	FIFTH RD	0	0	0	0	130	0	0	0	0	0	0	130	50	180	na
910	NARROGIN INN	0	135	0	0	831	50	260	0	0	0	0	1,276	0	1,276	75
911	GWYNNE PARK	0	0	0	70	150	40	0	0	0	0	0	260	0	260	na
913	SEVENTH AVE	0	0	0	0	240	0	0	0	0	0	0	240	0	240	na
914	NICHOLSON RD N	0	0	0	55	155	65	0	0	0	0	0	275	0	275	na
915	ROLEYSTONE	0	0	0	150	2,047	130	393	54	0	0	0	2,774	0	2,774	75
924	BROOKTON HWY	0	0	0	0	120	2	0	0	0	0	0	122	123	245	na
925	ARMADALE T CENTRE	0	47	160	713	34,807	2,740	10,164	3,562	2,939	1,179	1,034	57,345	2,672	60,017	1,614
926	MOUNTAIN VIEW	0	0	0	0	0	400	0	0	0	0	0	400	0	400	na
927	PEET RD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
928	SOLDIERS RD	0	0	0	0	60	25	230	0	200	0	0	515	0	515	na
929	KELMSCOTT HOTEL	0	0	0	0	846	0	0	0	1,000	0	0	1,846	0	1,846	na
930	ROCK INN TAVERN	0	0	0	0	200	0	0	0	200	0	0	400	0	400	na
931	ARMADALE HIGH SCHOOL	0	0	0	0	80	270	0	0	0	0	0	350	0	350	na
932	RIVER RD	0	0	0	0	410	0	0	0	0	0	0	410	0	410	na
933	FORRESTDALE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
934	NICHOLSON RD S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA) PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	EMPLOYMENT (persons) TOTAL
935	FARM EQUIPMENT	0	0	0	0	0	0	0	200	0	0	0	200	0	200	na
936	TURNER	0	86	0	0	30	0	401	166	30	0	0	713	0	713	33
937	ARMATAGE	0	0	0	0	0	0	0	0	0	65	0	65	154	219	na
938	SECOND ROAD	0	0	0	0	0	0	110	0	375	0	0	485	0	485	na
939	FOURTH ROAD	0	0	0	0	821	1,892	0	597	966	0	0	4,276	120	4,396	53
941	SEAFORTH AVE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL		**0**	**268**	**160**	**2,724**	**61,672**	**10,568**	**14,057**	**4,776**	**6,964**	**3,077**	**1,148**	**105,414**	**4,392**	**109,806**	**2,852**
1997																
59	ISOLATED USES-OUT SE *	0	156	0	0	120	2,200	192	240	0	2,160	80	5,148	0	5,148	130
100	SERVICE STATION *	0	0	0	270	460	596	0	0	0	0	0	1,326	0	1,326	23
900	KELMSCOTT CENTRE	0	40	0	1,147	15,806	3,690	2,004	834	420	0	114	24,055	2,442	26,497	729
901	CONNELL AVE	0	0	0	0	100	0	0	0	0	0	0	100	0	100	na
902	WESTFIELD	0	0	0	100	2,453	30	0	100	465	0	0	3,148	230	3,378	82
904	ARMSTRONG RD	0	0	0	0	288	0	58	0	0	0	0	346	0	346	na
906	SCHRUTH ST	0	0	0	0	150	0	0	0	0	0	0	150	0	150	na
907	CHALLIS	0	0	0	0	400	0	0	0	0	0	0	400	0	400	na
908	WEST ARMADALE	0	0	0	0	2,510	0	234	0	310	0	0	3,054	701	3,755	88
909	FIFTH RD	0	0	0	0	0	0	0	180	0	0	0	180	0	180	4
910	NARROGIN INN	0	0	0	0	874	0	260	100	200	20	0	1,454	492	1,946	72
911	GWYNNE PARK	0	0	0	70	150	40	0	0	0	0	0	260	0	260	na
913	SEVENTH AVE	0	0	0	0	305	0	0	0	0	0	0	305	0	305	na
914	NICHOLSON RD N	0	0	0	55	155	65	0	0	0	0	0	275	0	275	na
915	ROLEYSTONE	0	0	0	150	1,909	130	904	0	500	0	0	3,593	122	3,715	137
924	BROOKTON HWY	0	0	0	0	230	0	0	0	0	0	0	230	0	230	na
925	ARMADALE T CENTRE	0	0	250	533	33,964	1,920	10,381	3,626	2,476	1,179	1,474	55,803	5,501	61,304	1,798
926	MOUNTAIN VIEW	0	0	0	0	0	400	0	0	0	0	0	400	0	400	na
928	SOLDIERS RD	0	20	0	0	90	0	75	0	0	0	0	185	30	215	na
929	KELMSCOTT HOTEL	0	0	0	0	846	0	0	0	1,000	0	0	1,846	0	1,846	na
930	ROCK INN TAVERN	0	0	0	0	0	0	0	0	1,000	0	0	1,000	0	1,000	na
931	ARMADALE HIGH SCHOOL	0	0	0	0	130	270	0	0	0	0	0	400	0	400	na
932	RIVER RD	0	0	0	0	410	0	920	0	0	0	0	1,330	0	1,330	na
933	FORRESTDALE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
935	FARM EQUIPMENT	0	0	0	0	0	0	0	200	0	0	0	200	0	200	na
936	TURNER	0	101	0	0	0	0	245	226	0	0	0	572	230	802	30
937	ARMATAGE	0	0	0	0	0	0	1,308	154	0	0	0	1,462	0	1,462	46
938	CHAMPION DRIVE	0	0	0	120	100	0	845	800	0	0	0	1,865	110	1,975	23
939	TUDOR RD	0	0	0	120	1,021	1,692	200	697	0	0	0	3,730	788	4,518	104
941	SEAFORTH AVE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
968	RAILWAY AVE	0	0	0	0	0	400	0	0	0	0	0	400	0	400	na
TOTAL		**0**	**317**	**250**	**2,565**	**62,471**	**11,433**	**17,626**	**7,157**	**6,371**	**3,359**	**1,668**	**113,217**	**10,646**	**123,863**	**3,473**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B2: Town of Bassendean commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1990																
53	ISOLATED USES-IN NE	0	0	0	0	65	0	30	0	0	0	0	95	0	95	na
100	SERVICE STATION	0	0	0	150	0	60	0	0	0	0	0	210	0	210	na
350	BASSENDEAN VILLAGE	0	0	200	1,553	10,385	1,300	3,459	95	1,743	0	0	18,735	2,684	21,419	476
351	EDEN HILL	0	0	0	240	2,444	52	82	0	0	0	36	2,854	90	2,944	76
352	IDA STREET	0	0	82	195	1,691	25	0	0	200	0	0	2,193	30	2,223	59
353	PEARSON STREET	0	0	0	0	200	0	0	0	1,000	0	0	1,200	0	1,200	na
354	WEST ROAD	0	0	0	0	75	0	0	0	0	0	0	75	0	75	na
355	COLSTOUN ROAD	0	0	0	0	685	0	0	0	0	0	0	685	110	795	na
TOTAL		**0**	**0**	**282**	**2,138**	**15,545**	**1,437**	**3,571**	**95**	**2,943**	**0**	**36**	**26,047**	**2,914**	**28,961**	**651**
1993																
53	ISOLATED USES-IN NE	0	0	0	0	65	0	100	0	0	0	0	165	0	165	na
100	SERVICE STATION	0	0	0	150	0	60	0	0	0	0	0	210	0	210	na
350	BASSENDEAN VILLAGE	0	0	200	798	12,404	860	3,417	77	1,865	0	0	19,621	957	20,578	460
351	EDEN HILL	0	0	0	240	2,322	16	82	0	0	0	0	2,660	284	2,944	57
352	IDA STREET	0	0	82	195	1,585	40	0	0	200	0	0	2,102	196	2,298	47
353	PEARSON STREET	0	0	0	0	200	0	0	0	1,000	0	0	1,200	0	1,200	na
354	WEST ROAD	0	0	0	0	75	0	0	0	0	0	0	75	0	75	na
355	COLSTOUN ROAD	0	0	0	0	625	0	0	0	0	0	0	625	170	795	na
TOTAL		**0**	**0**	**282**	**1,383**	**17,276**	**976**	**3,599**	**77**	**3,065**	**0**	**0**	**26,658**	**1,607**	**28,265**	**591**
1997																
350	BASSENDEAN VILLAGE	0	0	200	878	11,176	823	3,792	77	1,825	0	76	18,847	1,222	20,069	492
351	EDEN HILL	0	0	0	200	179	16	0	0	0	0	0	395	2,549	2,944	29
352	IDA STREET	0	0	82	195	1,362	25	0	0	200	0	0	1,864	434	2,298	41
353	PEARSON STREET	0	0	0	0	200	0	0	0	1,000	0	0	1,200	0	1,200	na
354	WEST ROAD	0	0	0	0	75	0	0	0	0	0	0	75	0	75	na
355	COLSTOUN ROAD	0	0	0	0	570	60	0	0	0	0	0	630	120	750	na
356	BASSENDEAN ISO USES	0	0	0	150	65	60	100	0	0	0	0	375	0	375	na
TOTAL		**0**	**0**	**282**	**1,423**	**13,627**	**984**	**3,892**	**77**	**3,025**	**0**	**76**	**23,386**	**4,325**	**27,711**	**595**

** Part Complex. Balance in adjoining local government area(s).*

Figure B3: City of Bayswater commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA) PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	EMPLOYMENT (persons) TOTAL
1997																
52	ISOLATED USES-IN NW *	0	0	50	0	260	0	0	0	0	0	0	310	334	644	na
53	ISOLATED USES-IN NE	0	0	0	0	0	0	360	0	0	150	0	510	70	580	na
100	SERVICE STATION *	0	0	0	250	0	110	0	0	0	0	0	360	0	360	na
168	ROSS'S	0	0	0	0	1,725	1,600	3,652	0	0	0	0	6,977	0	6,977	na
214	LORD ST *	0	0	0	0	0	180	0	0	0	0	0	180	0	180	na
257	PENINSULAR ROAD	0	0	0	40	71	0	0	0	0	0	0	111	71	182	na
258	CALEDONIAN AVENUE	0	0	79	0	371	0	181	0	0	0	0	631	702	1,333	na
259	FIRST AVE EAST	0	0	0	70	0	10	0	0	0	0	0	80	100	180	na
268	WALTER ROAD *	0	110	0	254	1,756	0	498	0	0	0	0	2,618	1,657	4,275	68
271	MAYLANDS	0	130	0	869	10,796	495	3,332	95	1,600	0	64	17,381	4,858	22,239	507
283	EAST STREET	0	0	85	0	207	0	10	0	143	0	0	445	75	520	na
287	KENILWORTH STREET	0	0	0	100	252	100	70	0	0	0	0	522	100	622	na
301	COODE ST/WALTER RD *	0	0	0	100	0	60	0	0	1,892	0	0	2,052	0	2,052	30
302	SALISBURY STREET *	0	0	10	60	6,777	0	400	0	0	0	0	7,247	320	7,567	140
346	PENINSULAR HOTEL	0	0	0	150	272	100	0	0	3,160	0	0	3,682	0	3,682	na
347	FERGUSON STREET	0	0	0	150	0	0	0	0	0	0	0	150	235	385	na
349	THIRD AVENUE EAST	0	0	0	160	0	50	0	0	0	0	0	210	0	210	na
360	MORLEY-GALLERIA	0	15,148	15,306	33,381	88,082	22,417	17,204	4,578	11,119	0	1,218	208,453	23,923	232,376	5,290
361	NORANDA SQUARE	0	0	0	135	10,004	155	990	60	0	0	9	11,353	259	11,612	283
362	MAY STREET	0	0	0	120	120	0	115	90	230	0	0	675	0	675	61
363	MELTHAM STATION	0	0	80	50	380	0	70	0	0	0	0	580	0	580	na
364	GRAND PROMENADE	0	62	0	0	1,175	0	235	0	252	0	5	1,729	100	1,829	37
365	GARRATT ROAD	0	0	0	320	350	1,145	0	0	0	0	0	1,815	445	2,260	57
366	EMBLETON	0	0	0	0	420	0	0	0	0	0	0	420	0	420	na
367	LINCOLN VILLAGE	0	0	0	0	865	0	0	0	0	0	0	865	45	910	35
368	WELLINGTON VILLAGE	0	0	0	170	989	40	80	0	0	0	0	1,279	0	1,279	46
369	CRIMEA STREET	0	0	0	0	816	0	0	0	0	0	0	816	80	896	30
370	HAMPTON SQUARE	0	0	0	0	386	0	0	0	0	0	0	386	140	526	na
371	TURON STREET WEST	0	0	0	0	470	0	0	0	120	0	0	590	0	590	na
372	WHATLEY CRESCENT	0	110	0	0	1,585	0	1,883	300	0	0	300	4,178	1,415	5,593	114
373	BEECHBORO ROAD	0	0	500	110	2,396	40	350	600	704	0	0	4,700	528	5,228	372
374	SHAFTSBURY AVENUE	0	66	50	350	994	8	290	0	0	0	0	1,758	120	1,878	34
375	BROUN AVE	0	0	60	0	180	0	113	0	0	0	0	353	0	353	na
376	CAMBOON ROAD	0	0	0	0	0	350	0	0	0	0	0	350	0	350	na
377	THORNTON STREET	0	0	0	0	0	155	160	0	0	0	0	315	150	465	na
378	ROBERTS STREET	0	0	0	0	310	0	420	0	0	0	0	730	0	730	34
379	HARDY ROAD	0	80	80	0	70	0	0	0	0	0	0	230	240	470	na
380	BENARA RD MORLEY	0	0	0	250	4,630	200	333	0	0	0	0	5,413	0	5,413	247
381	DESCHAMP ROAD	0	0	0	0	184	0	0	0	0	0	0	184	0	184	na
382	TURON STREET	0	0	0	0	200	0	0	0	0	0	0	200	0	200	na
383	BEECHBORO ROAD NORTH	0	175	0	0	816	0	583	0	0	0	0	1,574	200	1,774	62
384	SLADE STREET	0	0	0	0	412	500	0	0	0	0	0	912	0	912	na
958	WHATLEY	0	0	0	297	0	98	0	0	0	0	0	395	0	395	na
TOTAL		**0**	**15,881**	**16,300**	**37,386**	**138,321**	**27,813**	**31,329**	**5,723**	**19,220**	**150**	**1,596**	**293,719**	**36,167**	**329,886**	**7,698**

* *Part Complex. Balance in adjoining local government area(s).*

Figure B4: City of Canning commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
578	SEVENOAKS STREET	0	0	0	60	2,524	10	460	900	0	0	20	3,974	1,110	5,084	101
580	MILLS STREET	0	0	0	0	1,854	260	639	0	0	0	0	2,753	0	2,753	73
582	EAST CANNINGTON	0	55	0	0	91	55	0	0	0	0	0	201	325	526	na
584	CANNINGTON HOTEL	0	100	0	0	1,160	1,490	0	140	0	0	0	2,890	360	3,250	29
585	BICKLEY ROAD *	0	0	0	290	973	1,391	0	272	0	0	0	2,926	0	2,926	75
586	WHARF STREET	0	0	0	60	241	35	0	0	0	0	0	336	64	400	na
587	MANNING ROAD	0	0	50	60	790	380	150	250	0	0	0	1,680	0	1,680	59
588	FIFTH AVENUE	0	0	0	0	0	0	120	0	0	0	0	120	0	120	na
589	CORINTHIAN CRESCENT	0	0	0	0	0	0	80	0	0	0	0	80	0	80	na
591	BURSARIA CRESCENT	0	0	0	0	0	0	80	0	0	0	0	80	0	80	na
592	SANDOWN ROAD	0	0	0	0	80	0	0	0	0	0	0	80	0	80	na
593	CAPRICE ROAD	0	0	0	0	0	0	100	0	0	0	0	100	40	140	na
596	CANNINGTON STATION	0	0	0	0	237	0	0	0	0	0	0	237	68	305	na
597	HIGH RD	0	0	0	80	130	40	0	127	0	0	0	377	0	377	na
959	CANNING VALE STH *	0	0	0	142	0	112	0	0	0	0	0	254	0	254	na
8701	ANDREA WAY	0	0	0	100	0	44	80	0	0	0	0	224	0	224	na
TOTAL		**0**	**6,931**	**21,561**	**11,080**	**119,518**	**54,109**	**27,421**	**3,958**	**17,956**	**3,200**	**5,262**	**270,996**	**18,933**	**289,929**	**6,160**
1997																
100	SERVICE STATION *	0	0	0	200	0	50	0	0	0	0	0	250	0	250	na
208	ALDAY ST *	0	0	0	0	0	80	150	0	0	0	0	230	250	480	na
559	CANNINGTON	0	6,711	20,833	8,040	49,803	18,521	34,465	142	11,244	1,700	4,125	155,584	7,667	163,251	3,337
560	SOUTHLANDS	0	0	51	257	15,893	627	935	65	4,738	0	0	22,566	954	23,520	918
561	RIVERTON FORUM	0	0	0	135	15,645	150	708	53	2,602	1,000	70	20,363	1,201	21,564	560
562	GLENMOY AVENUE	0	0	0	0	1,225	0	527	75	0	0	0	1,827	200	2,027	69
563	RIVERTON DRIVE EAST	0	0	0	0	447	0	0	0	0	0	0	447	0	447	22
564	CENTRAL ROAD	0	0	0	0	1,106	0	99	0	0	0	5	1,210	650	1,860	49
565	SHELLEY HUB	0	0	0	80	859	40	206	0	0	0	2	1,187	192	1,379	71
566	BARBICAN STREET	0	0	0	220	715	40	200	0	0	0	0	1,175	0	1,175	46
567	HERALD AVENUE	0	10	1,533	1,250	6,212	13,884	3,234	180	350	0	0	26,653	1,306	27,959	406
568	WOODPECKER AVENUE	0	0	0	60	1,340	110	260	0	0	0	0	1,770	368	2,138	115
569	LYNWOOD AVENUE	0	0	0	0	2,955	66	242	0	200	0	0	3,463	563	4,026	127
570	PARKWOOD SQUARE	0	0	0	0	483	0	397	0	0	0	0	880	984	1,864	57
572	BENTLEY	0	1,048	1,389	1,930	13,172	6,499	7,519	386	683	0	187	32,813	3,832	36,645	727
573	TREASURE ROAD	0	0	0	0	544	0	0	0	0	0	0	544	140	684	na
574	QUEENS PARK	0	0	0	50	910	0	0	0	770	150	0	1,880	0	1,880	27
575	HILLVIEW TERRACE	0	0	0	0	921	0	0	0	0	0	0	921	0	921	na
576	EUREKA ROAD	0	0	0	85	550	215	0	0	0	0	0	850	84	934	32
577	CHAPMAN ROAD	0	0	0	0	1,680	0	50	0	0	0	0	1,730	505	2,235	41
578	SEVENOAKS STREET	0	0	0	0	2,326	0	698	78	0	0	20	3,122	938	4,060	87
579	CANNING VALE	0	100	600	430	560	60	590	0	0	0	0	2,340	210	2,550	85
580	MILLS STREET	0	0	532	0	1,306	478	825	70	0	0	0	3,211	160	3,371	95
582	EAST CANNINGTON	0	0	0	0	91	0	0	0	0	0	0	91	435	526	na
584	CANNINGTON HOTEL	0	100	800	0	8,563	1,380	1,380	800	0	0	120	13,143	550	13,693	85
585	BICKLEY ROAD *	0	0	0	519	1,486	2,285	0	332	0	0	0	4,622	1,640	6,262	103
586	WHARF STREET	0	0	0	60	241	35	0	64	0	0	0	400	0	400	na
587	MANNING ROAD	0	0	50	60	655	380	0	250	0	0	0	1,395	285	1,680	36
589	CORINTHIAN CRESCENT	0	0	0	0	0	0	80	0	0	0	0	80	0	80	na
592	SANDOWN ROAD	0	0	0	0	0	0	0	80	0	0	0	80	0	80	na
593	CAPRICE ROAD	0	0	0	0	0	0	0	0	0	0	0	0	150	150	0
596	CANNINGTON STATION	0	0	0	0	255	0	0	0	0	0	0	255	150	405	na
597	HIGH RD	0	0	0	80	130	108	0	127	0	0	0	445	0	445	31
959	CANNING VALE STH *	0	0	0	142	822	112	0	320	0	0	0	1,396	690	2,086	115
964	HILLROWE GROUP	0	0	0	0	0	0	556	0	0	0	16	572	98	670	24
8701	ANDREA WAY	0	0	0	100	0	44	0	0	0	0	0	144	0	144	na
TOTAL		**0**	**7,969**	**25,788**	**13,698**	**130,895**	**45,164**	**53,121**	**3,022**	**20,587**	**2,850**	**4,545**	**307,639**	**24,202**	**331,841**	**7,354**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B5: City of Fremantle commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA) PRIMARY/RURAL	MANUFACTURING/PROCESSING/FABRICATION	STORAGE/DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/BUSINESS	HEALTH/WELFARE/COMMUNITY SERVICES	ENTERTAINMENT/RECREATIONAL/CULTURAL	RESIDENTIAL	UTILITIES/COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	EMPLOYMENT (persons) TOTAL
410	HAMILTON HILL *	0	6,583	11,561	10,423	6,377	8,376	14,146	600	0	0	4,617	62,683	3,494	66,177	901
411	WINTERFOLD	0	0	0	100	2,283	30	85	60	0	0	0	2,558	104	2,662	82
412	HILTON PARK	0	0	216	220	5,336	270	588	55	1,160	0	5	7,850	860	8,710	206
413	PAGET ST	0	0	0	0	161	0	0	70	0	0	0	231	0	231	na
415	GEORGE ST E FREM *	0	0	0	300	0	42	0	0	0	0	0	342	0	342	na
680	PIER 21	0	2,715	0	986	50	770	441	0	0	2,378	2,400	9,740	0	9,740	55
TOTAL		**0**	**30,081**	**185,401**	**40,463**	**141,484**	**36,186**	**113,905**	**23,594**	**47,470**	**25,630**	**30,860**	**675,074**	**53,547**	**728,621**	**11,576**
1993																
54	ISOLATED USES-IN SW *	0	1,690	0	674	1,474	482	870	72	950	227	0	6,439	1,247	7,686	330
391	PALMYRA *	0	0	0	120	0	450	0	300	0	0	0	870	0	870	na
395	DOURO ROAD	0	0	0	401	500	0	100	0	0	0	0	1,001	60	1,061	30
396	WHITE GUM VALLEY	0	0	400	150	1,921	100	180	0	0	70	0	2,821	230	3,051	55
398	WINTERFOLD ROAD *	0	0	0	120	0	25	0	0	0	0	0	145	0	145	na
399	McCOMBE AVE	0	0	0	0	559	0	0	0	0	0	0	559	0	559	na
400	FREMANTLE CITY CENTRE	0	9,778	113,445	5,207	94,320	5,597	64,524	15,092	33,738	22,219	17,541	381,461	39,113	420,574	7,509
401	QUEEN VICTORIA	0	0	33,148	4,197	12,431	11,365	6,287	3,600	3,227	2,100	2,377	78,732	4,499	83,231	527
402	QUEENS SQUARE	0	80	120	145	0	15	5,643	1,485	0	98	50	7,636	819	8,455	393
403	HARVEST RD	0	722	680	2,744	5,145	160	824	0	420	70	178	10,943	1,520	12,463	135
404	NORTH FREMANTLE	0	1,777	2,840	3,166	2,724	751	3,609	1,793	2,300	0	0	18,960	270	19,230	394
405	MARINE TCE FREM	0	2,975	9,605	1,647	3,581	1,655	6,094	93	780	420	74	26,924	6,986	33,910	451
406	SOUTH FREMANTLE	0	855	6,820	10,235	3,039	1,565	755	1,305	1,659	2,450	6,051	34,734	6,259	40,993	506
407	STEVENS ST	0	1,200	0	0	33	0	230	0	0	0	0	1,463	0	1,463	23
408	WRAY AVE	0	120	660	548	2,172	592	701	65	1,280	120	0	6,258	842	7,100	157
409	LEFROY RD	0	0	0	0	437	0	1,980	0	0	0	0	2,417	0	2,417	80
410	HAMILTON HILL *	0	7,019	10,071	12,965	6,269	7,164	11,471	600	3,690	0	3,237	62,486	5,521	68,007	736
411	WINTERFOLD	0	0	0	0	2,387	0	85	60	0	0	0	2,532	0	2,532	71
412	HILTON PARK	0	0	306	300	5,014	270	644	0	1,380	0	5	7,919	705	8,624	190
413	PAGET ST	0	0	0	0	161	0	0	70	0	0	0	231	0	231	34
415	GEORGE ST E FREM *	0	0	0	300	0	42	0	0	0	0	0	342	0	342	na
680	PIER 21	0	55	0	1,376	100	770	441	0	0	2,378	0	5,120	0	5,120	59
TOTAL		**0**	**26,271**	**178,095**	**44,295**	**142,267**	**31,003**	**104,438**	**24,535**	**49,424**	**30,152**	**29,513**	**659,993**	**68,071**	**728,064**	**11,727**
1997																
54	ISOLATED USES-IN SW *	0	1,822	0	320	1,030	102	300	47	600	0	0	4,221	1,045	5,266	124
391	PALMYRA *	0	0	0	120	300	450	0	0	0	0	0	870	0	870	na
395	DOURO ROAD	0	0	0	401	410	0	1,000	0	0	0	0	1,811	400	2,211	42
396	WHITE GUM VALLEY	0	0	80	150	2,131	70	180	0	0	0	0	2,611	50	2,661	66
397	SOUTH ST	0	0	0	100	219	300	70	0	0	0	0	689	60	749	20
398	WINTERFOLD ROAD *	0	0	0	120	0	25	0	0	0	0	0	145	0	145	na
399	McCOMBE AVE	0	0	0	0	506	0	0	0	0	0	0	506	53	559	na
400	FREMANTLE CITY CENTRE	0	7,420	12,894	3,654	91,065	5,118	64,190	22,364	31,761	20,452	13,839	272,757	140,248	413,005	7,250
401	QUEEN VICTORIA	0	570	31,870	7,393	8,759	15,510	7,672	2,385	3,117	2,100	0	79,376	5,680	85,056	567
402	QUEENS SQUARE	0	0	137	491	0	80	5,326	1,795	0	220	0	8,049	805	8,854	357
403	HARVEST RD	0	25	2,722	1,429	4,904	160	738	0	70	0	78	10,126	2,071	12,197	136
404	NORTH FREMANTLE	0	1,097	1,205	577	1,879	356	6,219	1,140	2,300	0	0	14,773	3,328	18,101	314
405	MARINE TCE FREM	25	750	1,833	1,710	3,679	1,755	4,204	0	780	200	194	15,135	2,347	17,482	471
406	SOUTH FREMANTLE	0	400	6,310	10,567	3,776	1,395	735	0	1,747	3,847	6,051	34,828	5,492	40,320	537
407	STEVENS ST	0	0	0	0	0	0	150	0	0	0	0	150	33	183	na
408	WRAY AVE	0	250	140	418	1,353	402	810	65	1,280	0	0	4,718	2,312	7,030	118
409	LEFROY RD	0	0	0	0	187	0	1,880	0	0	0	0	2,067	0	2,067	49
410	HAMILTON HILL *	430	6,940	18,433	11,561	6,810	6,993	5,475	600	4,142	0	249	61,633	5,871	67,504	745
411	WINTERFOLD	0	70	0	0	2,214	0	54	60	0	0	0	2,398	134	2,532	83
412	HILTON PARK	0	60	216	116	4,808	240	843	360	1,360	0	50	8,053	1,852	9,905	204
413	PAGET ST	0	0	0	0	161	0	0	133	0	0	0	294	0	294	39
415	GEORGE ST E FREM *	0	0	0	150	0	42	0	0	0	0	0	192	0	192	na
519	EAST FREMANTLE *	0	0	0	118	80	15	0	0	0	0	0	213	0	213	na
965	BELLAMY ST	0	0	0	403	1,813	100	1,737	80	0	0	0	4,133	1,530	5,663	173
TOTAL		**455**	**19,404**	**75,845**	**39,798**	**136,084**	**33,113**	**101,583**	**29,029**	**47,157**	**26,819**	**20,461**	**529,748**	**173,311**	**703,059**	**11,355**

** Part Complex. Balance in adjoining local government crea(s).*
na Not available

Figure B6: City of Cockburn commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA) PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	EMPLOYMENT (persons) TOTAL
1997																
54	ISOLATED USES-IN SW *	0	0	0	336	1,158	482	402	557	0	0	0	2,935	200	3,135	104
100	SERVICE STATION *	0	0	0	550	100	200	0	0	0	0	0	850	0	850	na
398	WINTERFOLD ROAD	0	0	0	0	255	0	0	0	0	0	0	255	0	255	na
410	HAMILTON HILL *	0	0	0	0	40	0	0	0	650	400	0	1,090	0	1,090	na
447	STRATTON STREET	0	0	0	0	240	0	0	0	0	0	0	240	100	340	na
450	PHOENIX PARK	0	0	46	325	19,781	90	3,723	60	123	0	45	24,193	525	24,718	924
451	HOBSONS AVE	0	0	0	0	50	0	100	0	0	0	0	150	0	150	na
452	BIBRA LAKE	0	0	100	0	1,010	0	350	0	0	0	0	1,460	143	1,603	34
453	YANGEBUP	0	0	0	0	1,599	150	165	150	0	0	0	2,064	174	2,238	75
454	COOLBELUP	0	0	0	140	3,545	60	452	473	1,694	0	0	6,364	502	6,866	134
455	FORREST ROAD	0	0	0	0	1,614	0	120	0	0	0	0	1,734	927	2,661	47
456	CARRINGTON ST HH	0	25	0	1,070	1,755	1,110	210	0	1,670	0	0	5,840	180	6,020	131
457	HAMILTON HILL TAVERN	0	0	0	0	3,414	400	507	0	568	200	0	5,089	1,352	6,441	149
458	ROCKINGHAM ROAD	0	106	0	360	1,548	227	128	0	1,200	0	0	3,569	330	3,899	64
459	SPEARWOOD ROAD	0	0	0	100	3,732	60	278	0	1,252	0	0	5,422	120	5,542	118
460	SOUTHWELL	0	0	0	0	355	0	80	0	0	0	0	435	50	485	na
461	COCKBURN LIQUOR	0	0	0	100	640	100	0	0	0	0	0	840	0	840	na
462	MEREVALE GDNS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
463	THE GRANGE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
464	HAMILTON ROAD	0	0	0	0	0	0	0	0	0	0	0	0	80	80	0
465	BARTRAM ROAD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
467	BERRIGAN DRIVE	0	0	0	85	3,099	65	130	840	270	0	0	4,489	191	4,680	120
468	JANDAKOT NORTH	0	0	0	110	430	60	0	0	0	0	6	606	0	606	28
470	WATTLEUP	0	0	0	100	675	70	0	0	200	0	0	1,045	550	1,595	18
953	ST. PAUL'S	0	0	0	0	170	0	70	0	0	0	0	240	340	580	na
954	FAVAZZO PLACE	0	0	0	600	0	0	0	0	0	0	0	600	0	600	na
955	LAKES SHOPPING CENTRE	0	24	0	96	5,824	992	321	849	151	0	55	8,312	516	8,828	288
960	ATWELL	0	0	0	0	350	0	0	0	0	0	0	350	0	350	na
967	GATEWAY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8735	YANGEBUP SHOPPING	0	0	0	90	451	100	0	0	0	0	0	641	72	713	46
8736	ADVENTURE WORLD	0	0	0	0	350	0	0	0	40	0	0	390	0	390	na
TOTAL		**0**	**155**	**146**	**4,062**	**52,185**	**4,166**	**7,036**	**2,929**	**7,818**	**600**	**106**	**79,203**	**6,352**	**85,555**	**2,391**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B7: City of Belmont commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA) PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	EMPLOYMENT (persons) TOTAL
1997																
498	HARDEY RD	0	0	0	0	0	0	0	0	0	0	0	0	170	170	0
500	BELMONT TOWN CENTRE	0	249	1,000	428	36,566	1,008	4,349	814	476	1,000	298	46,188	3,634	49,822	1,502
501	REDCLIFFE	0	0	780	270	385	1,741	788	68	323	0	150	4,505	225	4,730	109
502	BELGRAVIA STREET	0	0	0	0	1,238	0	140	0	0	0	0	1,378	471	1,849	43
503	WRIGHT STREET *	0	65	0	0	518	0	153	0	0	0	0	736	35	771	24
504	FRANCISCO STREET	0	585	0	0	269	0	40	0	0	0	0	894	0	894	na
505	BELVIDERE STREET	0	0	0	225	4,265	213	353	0	220	0	0	5,276	96	5,372	135
506	EPSOM AVENUE	0	0	0	0	1,230	190	330	0	0	0	100	1,850	230	2,080	56
507	KOOYONG ROAD	0	0	0	100	2,300	150	210	0	0	0	12	2,772	192	2,964	72
508	RIVERVALE	0	400	569	567	237	635	620	838	0	0	620	4,486	4,356	8,842	102
509	ARKABA	0	0	0	139	1,676	216	215	0	0	12,053	0	14,299	1,214	15,513	127
510	LOVE STREET	0	0	0	0	727	145	5	0	130	0	0	1,007	680	1,687	21
511	GEH WEST	0	961	6,796	3,969	5,171	1,178	24,792	3,553	695	8,270	900	56,285	6,479	62,764	1,019
512	GEH EAST	0	3,630	6,683	4,321	7,965	19,013	14,664	1,965	1,100	2,400	745	62,486	7,380	69,866	1,419
513	FAUNTLEROY	0	0	0	0	0	0	0	0	0	0	0	0	1,830	1,830	0
514	ASCOT INN	0	0	0	0	0	0	0	0	0	0	0	0	208	208	0
515	MARRACOONDA	0	0	0	0	90	0	0	0	0	2,150	0	2,240	0	2,240	na
516	BELMAY	0	0	150	350	295	0	1,138	250	0	0	0	2,183	135	2,318	29
557	BELMONT SQ	0	0	110	0	220	140	0	0	0	0	0	470	0	470	na
558	KEW ST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
571	BELMONT AVE	0	0	0	0	120	0	0	0	0	0	0	120	0	120	na
595	FINLAY CT	0	0	0	0	250	0	0	0	0	0	0	250	94	344	na
961	RACECOURSE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL		**0**	**5,641**	**15,088**	**9,941**	**26,956**	**23,621**	**43,448**	**6,674**	**2,468**	**24,873**	**2,527**	**161,237**	**23,625**	**184,862**	**4,736**

** Part Complex. Balance in adjoining local government area(s).*

na Not available

Figure B8: City of South Perth commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA) PRIMARY/RURAL	MANUFACTURING/PROCESSING/FABRICATION	STORAGE/DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/BUSINESS	HEALTH/WELFARE/COMMUNITY SERVICES	ENTERTAINMENT/RECREATIONAL/CULTURAL	RESIDENTIAL	UTILITIES/COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	EMPLOYMENT (persons) TOTAL
538	MORESBY STREET	0	65	0	100	350	0	0	0	0	0	0	515	0	515	na
539	COMO HOTEL	0	0	0	80	411	100	75	0	895	1,026	0	2,587	0	2,587	63
540	JUDD STREET	0	291	219	111	627	0	18,954	353	236	0	436	21,227	3,494	24,721	965
541	COODE ST S PERTH	0	0	0	200	0	40	40	0	0	0	0	280	0	280	na
542	TALBOT AVENUE	0	0	0	0	407	0	196	0	0	0	0	603	96	699	25
543	MANNING HOTEL	0	0	0	0	150	0	0	0	550	100	0	800	0	800	30
544	GODWIN AVENUE	0	0	0	50	60	0	0	0	0	0	0	110	60	170	na
545	MILL POINT ROAD	0	0	0	0	500	0	5,892	0	1,111	1,000	60	8,563	1,202	9,765	341
546	DOUGLAS AVENUE	0	0	0	250	339	120	170	0	0	0	0	879	0	879	26
547	LAWLER STREET	0	0	0	0	0	30	0	0	0	0	0	30	70	100	na
548	BANKSIA TERRACE	0	0	0	0	40	0	0	0	0	0	0	40	0	40	na
549	KENSINGTON	0	0	0	224	0	0	0	0	1,500	0	0	1,724	0	1,724	na
550	HENSMAN STREET	0	0	0	0	50	0	0	0	0	0	0	50	0	50	na
551	ARUNDEL STREET	0	0	0	0	0	0	0	0	0	0	0	0	120	120	0
552	FIRST AVENUE	0	0	0	0	40	0	0	0	0	0	0	40	0	40	na
553	BRANDON STREET	0	0	0	0	60	0	0	0	0	0	0	60	0	60	na
554	KENSINGTON P S	0	0	0	0	40	70	0	0	0	0	0	110	0	110	na
555	COMER STREET	0	0	0	0	85	0	0	0	0	0	0	85	0	85	na
556	THELMA STREET	0	0	0	0	0	0	110	0	0	0	0	110	0	110	na
8746	MONASH AVE	0	0	0	0	218	850	60	0	0	0	300	1,428	0	1,428	23
TOTAL		**0**	**526**	**1,247**	**5,181**	**33,130**	**3,440**	**44,043**	**4,344**	**14,980**	**18,552**	**1,106**	**126,549**	**9,837**	**136,386**	**4,480**
1997																
209	CANNING HWY/BERWICK *	0	0	0	170	600	75	2,082	0	0	0	0	2,927	123	3,050	191
520	COODE/STH TERRACE	0	0	0	50	609	30	837	2,878	0	0	175	4,579	0	4,579	185
521	GEORGE ST S PERTH	0	70	0	50	515	0	0	0	0	0	0	635	50	685	23
522	MONASH/MURRAY	0	0	0	60	440	75	0	0	0	0	0	575	96	671	na
523	HENLEY STREET	0	64	0	50	1,517	617	400	0	0	0	0	2,648	0	2,648	112
524	LETCHWORTH AVENUE	0	0	0	0	155	0	0	0	0	0	0	155	360	515	na
525	LEY STREET	0	0	0	0	912	30	188	0	550	0	0	1,680	120	1,800	55
526	BARKER AVENUE	0	100	0	124	840	82	157	0	0	0	0	1,303	0	1,303	74
527	RENWICK STREET	0	0	0	70	160	0	240	250	0	0	0	720	0	720	27
528	MENDS STREET	0	43	0	208	5,736	154	7,361	46	1,240	1,000	16	15,804	1,963	17,767	618
529	ANGELO STREET	0	0	748	355	2,586	140	2,116	0	300	0	134	6,379	270	6,649	266
530	PRESTON STREET	0	47	60	427	4,071	40	4,902	120	1,264	11,520	10	22,461	578	23,039	528
531	BIRDWOOD AVENUE	0	0	0	580	1,195	170	0	0	0	0	61	2,006	0	2,006	53
532	WELWYN AVENUE	0	0	0	100	1,538	125	60	90	0	0	0	1,913	147	2,060	57
533	KARAWARA	0	0	0	296	5,157	30	9	52	300	0	0	5,844	131	5,975	207
534	HURLINGHAM HOTEL	0	50	80	572	914	50	1,647	0	1,796	6,926	0	12,035	548	12,583	209
535	RHODES HOTEL	0	0	0	0	2,651	0	0	0	0	4,200	0	6,851	0	6,851	53
537	CLIFFE STREET	0	100	220	404	1,171	418	1,488	80	900	0	0	4,781	430	5,211	166
538	MORESBY STREET	0	65	0	100	350	0	0	0	0	0	0	515	0	515	na
539	COMO HOTEL	0	0	0	0	428	60	0	0	895	1,026	0	2,409	96	2,505	52
540	JUDD STREET	0	0	347	289	542	0	23,467	669	0	0	416	25,730	2,011	27,741	1,054
541	COODE ST S PERTH	0	0	0	200	0	40	40	0	0	0	0	280	0	280	na
542	TALBOT AVENUE	0	0	0	0	402	0	261	0	0	0	0	663	36	699	23
543	MANNING HOTEL	0	0	0	0	150	0	0	0	550	100	0	800	0	800	30
544	GODWIN AVENUE	0	0	0	50	120	0	0	0	0	0	0	170	0	170	na
545	MILL POINT ROAD	0	0	80	0	610	0	5,270	48	1,000	1,000	60	8,068	1,658	9,726	332
546	DOUGLAS AVENUE	0	0	0	500	339	120	340	0	0	0	0	1,299	0	1,299	27
547	LAWLER STREET	0	0	0	0	70	70	0	0	0	0	0	140	0	140	na
548	BANKSIA TERRACE	0	0	0	0	40	0	0	0	0	0	0	40	0	40	na
549	KENSINGTON	0	0	0	120	0	0	0	0	1,500	0	0	1,620	0	1,620	na
550	HENSMAN STREET	0	0	0	0	50	0	0	0	0	0	0	50	0	50	na
551	ARUNDEL STREET	0	0	0	0	0	0	0	0	0	0	0	0	120	120	0
552	FIRST AVENUE	0	0	0	0	0	0	0	0	0	0	0	0	40	40	0
553	BRANDON STREET	0	0	0	0	60	0	0	0	0	0	0	60	0	60	na
554	KENSINGTON P S	0	0	0	0	0	0	0	0	110	0	0	110	0	110	0
555	COMER STREET	0	0	0	0	85	0	0	0	0	0	0	85	0	85	na
556	THELMA STREET	0	0	0	0	0	0	110	0	0	0	0	110	0	110	na
8746	MONASH AVE	0	0	0	0	342	25	0	0	0	0	0	367	0	367	na
TOTAL		**0**	**539**	**1,535**	**4,775**	**34,355**	**2,351**	**50,975**	**4,233**	**10,405**	**25,772**	**872**	**135,812**	**8,777**	**144,589**	**4,423**

* *Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B9: Town of Victoria Park commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1997																
52	ISOLATED USES-IN NW *	0	0	0	0	540	0	0	0	0	0	0	540	0	540	na
164	VIC PARK EAST	0	0	0	415	1,481	375	695	200	0	0	0	3,166	436	3,602	68
199	COLLIER TECH PARK	0	12,451	0	10,299	0	0	9,334	150	0	0	0	32,234	2,845	35,079	941
200	VICTORIA PARK	40	2,112	16,470	19,104	27,328	21,014	52,708	3,679	4,376	450	1,423	148,704	36,321	185,025	3,824
201	EAST VICTORIA PARK	0	794	769	1,155	24,937	2,136	9,976	1,061	3,009	0	154	43,991	5,374	49,365	1,464
208	ALDAY ST *	0	140	530	1,640	5,598	4,420	915	0	0	0	0	13,243	1,860	15,103	338
209	CANNING HWY/BERWICK *	0	75	100	150	1,772	3,662	2,385	500	1,080	0	0	9,724	1,337	11,061	346
211	ARCHER ST	0	0	248	430	3,168	279	270	0	0	0	60	4,455	120	4,575	102
222	ORRONG RD/ARCHER ST	0	0	0	0	790	100	0	0	0	0	0	890	0	890	na
223	LATHLAIN	0	530	200	150	675	480	155	84	0	0	0	2,274	666	2,940	34
224	ETWELL ST	0	0	0	0	130	0	50	0	0	0	0	180	310	490	na
225	ORRONG RD	0	0	0	120	675	40	90	0	0	0	0	925	0	925	23
230	RED CASTLE	0	634	250	400	1,136	600	215	0	1,702	2,718	100	7,755	1,184	8,939	119
231	SUSSEX	0	0	0	176	520	65	0	0	0	0	0	761	234	995	33
232	OATS ST	0	0	555	500	520	20	0	0	0	0	18	1,613	45	1,658	na
233	TUCKETT ST	0	50	150	0	0	220	340	0	0	0	0	760	1,200	1,960	na
234	COHN ST	0	234	1,932	1,437	124	700	30	1,574	181	0	0	6,212	253	6,465	50
250	CARLISLE	0	0	0	650	270	40	546	98	85	240	0	1,929	0	1,929	58
503	WRIGHT STREET *	0	0	0	65	65	0	0	0	0	0	0	130	60	190	na
952	VIC PARK – ISO USES	0	200	0	100	349	0	25	0	0	0	0	674	60	734	26
TOTAL		**40**	**17,220**	**21,204**	**36,791**	**70,078**	**34,151**	**77,734**	**7,346**	**10,433**	**3,408**	**1,755**	**280,160**	**52,305**	**332,465**	**7,520**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B10: City of Gosnells commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA) PRIMARY/RURAL	MANUFACTURING/PROCESSING/FABRICATION	STORAGE/DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/BUSINESS	HEALTH/WELFARE/COMMUNITY SERVICES	ENTERTAINMENT/RECREATIONAL/CULTURAL	RESIDENTIAL	UTILITIES/COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	EMPLOYMENT (persons) TOTAL
492	MADDINGTON COMPLEX	0	625	321	1,862	34,509	4,810	6,497	524	2,431	216	158	51,953	4,047	56,000	1,342
493	SPENCER VILLAGE	0	0	0	0	1,750	75	95	0	0	0	0	1,920	200	2,120	156
494	W GOSNELLS	0	0	0	180	479	40	190	0	150	0	0	1,039	0	1,039	45
495	KENWICK VILLAGE	0	0	0	170	827	50	120	0	0	0	0	1,167	506	1,673	36
496	LADYWELL	0	0	0	710	0	320	0	0	0	0	0	1,030	0	1,030	na
497	BECKENHAM	0	0	0	130	1,189	110	0	0	0	0	0	1,429	0	1,429	42
499	GOSNELLS CITY COUNCIL	0	0	250	1,780	18,189	6,135	6,975	200	1,712	400	0	35,641	1,149	36,790	1,061
517	WARTON RD	0	0	0	263	713	0	1,611	250	0	0	0	2,837	0	2,837	125
585	BICKLEY ROAD *	0	360	0	372	820	285	0	0	0	0	0	1,837	450	2,287	33
598	REDFOX CRES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL		**0**	**1,645**	**1,571**	**8,773**	**87,654**	**16,282**	**19,047**	**6,179**	**8,880**	**716**	**277**	**151,024**	**8,899**	**159,923**	**4,385**
1997																
55	ISOLATED USES-IN SE	0	0	0	0	808	0	0	0	0	0	0	808	0	808	na
100	SERVICE STATION *	0	0	0	120	0	30	0	0	0	0	0	150	0	150	na
472	KELVIN ROAD	0	0	0	0	85	0	8	0	0	0	0	93	0	93	na
473	WHEATLEY CRESCENT	0	0	580	0	385	0	170	150	0	0	0	1,285	40	1,325	32
474	STALKER ROAD	0	0	0	0	0	600	0	0	0	0	0	600	0	600	na
475	FREMANTLE ROAD	0	0	0	76	0	0	324	76	0	0	0	476	0	476	20
476	YULE BROOK	0	0	0	25	200	130	0	0	1,350	0	0	1,705	0	1,705	30
477	JUBILEE STREET	0	0	260	0	0	0	514	0	0	0	0	774	0	774	na
478	LACEY STREET	0	0	0	20	0	0	250	0	0	0	0	270	0	270	na
479	WILLIAM STREET	0	65	0	60	85	40	0	4,170	0	0	0	4,420	0	4,420	83
482	GOSNELLS – ISO USES	0	0	0	0	80	20	0	0	0	0	0	100	50	150	na
483	MARTINDALE	0	0	0	0	302	0	0	0	0	0	0	302	0	302	na
484	MURDOCH ROAD	0	0	0	55	5,913	80	559	90	972	0	0	7,669	195	7,864	287
485	CORFIELD STREET	0	80	0	0	1,932	0	0	0	400	0	0	2,412	382	2,794	48
486	S GOSNELLS	0	0	0	0	1,729	0	170	0	0	0	0	1,899	80	1,979	52
487	HUNTINGDALE	0	0	0	180	898	280	0	0	0	0	0	1,358	0	1,358	49
488	LANGFORD VILLAGE	0	0	0	150	1,867	236	519	410	615	0	0	3,797	688	4,485	133
489	KENWICK	0	70	0	150	581	460	250	380	0	0	0	1,891	617	2,508	43
490	THORNLIE SQUARE	0	0	0	74	11,492	243	761	121	553	200	119	13,563	1,837	15,400	378
491	WESTFIELD STREET	0	63	0	72	3,995	221	300	0	310	0	0	4,961	155	5,116	162
492	MADDINGTON COMPLEX	0	330	171	2,497	32,141	5,316	8,044	629	1,720	216	158	51,222	6,100	57,322	1,400
493	SPENCER VILLAGE	0	0	0	0	2,374	0	0	0	0	0	0	2,374	329	2,703	135
494	W GOSNELLS	0	0	0	180	383	40	190	0	2,537	0	0	3,330	96	3,426	41
495	KENWICK VILLAGE	0	0	45	90	1,108	50	120	0	0	0	6	1,419	120	1,539	57
496	LADYWELL	0	0	0	560	0	280	250	0	0	0	0	1,090	40	1,130	21
497	BECKENHAM	0	0	0	151	1,391	116	0	0	0	0	20	1,678	50	1,728	47
499	GOSNELLS CITY COUNCIL	0	120	320	1,420	16,548	5,708	8,080	738	1,712	400	80	35,126	3,328	38,454	1,092
517	WARTON RD	0	0	0	0	392	0	1,823	250	0	0	0	2,465	195	2,660	139
585	BICKLEY ROAD *	0	0	140	160	1,270	300	0	0	0	0	0	1,870	500	2,370	42
598	REDFOX CRES	0	0	0	0	1,820	0	0	0	0	0	0	1,820	360	2,180	na
956	LANGFORD	0	0	0	180	0	125	0	0	0	0	0	305	207	512	na
959	CANNING VALE STH *	0	0	0	0	962	0	177	0	0	0	0	1,139	65	1,204	36
TOTAL		**0**	**728**	**1,516**	**6,220**	**88,741**	**14,275**	**22,509**	**7,014**	**10,169**	**816**	**383**	**152,371**	**15,434**	**167,805**	**4,439**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B11: City of Joondalup commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1997																
56	ISOLATED USES-OUT NW	0	0	0	140	700	330	0	350	750	0	0	2,270	0	2,270	34
600	JOONDALUP CITY	0	100	668	1,179	31,745	771	25,426	24,762	14,760	0	154	99,565	10,689	110,254	2,624
601	WARWICK GROVE *	0	0	0	573	21,995	100	2,198	880	4,629	0	0	30,375	1,377	31,752	1,177
602	WHITFORDS CITY	0	161	587	143	40,007	8,050	4,609	845	9,272	0	0	63,674	3,667	67,341	1,922
605	SORRENTO	0	24	0	80	954	40	0	0	25	0	0	1,123	326	1,449	37
606	FORREST PLAZA	0	0	0	48	598	0	270	0	0	0	0	916	115	1,031	33
607	SPRINGFIELD	0	0	0	0	1,068	0	0	0	0	0	0	1,068	0	1,068	31
609	GREENWOOD VILLAGE	0	0	0	210	3,092	159	1,243	50	6,050	0	372	11,176	458	11,634	297
610	DUNCRAIG	0	0	0	342	1,986	188	251	0	0	0	0	2,767	255	3,022	137
611	SHEPPARD WAY	0	0	0	100	2,011	25	461	69	0	0	5	2,671	160	2,831	133
612	GLENGARRY	0	0	0	40	3,136	163	2,465	47	460	0	60	6,371	185	6,556	400
613	COOLIBAH PLAZA	0	0	0	0	1,003	0	60	0	0	0	0	1,063	0	1,063	61
614	CARINE GLADES	0	0	0	33	2,890	33	660	250	2,230	0	0	6,096	53	6,149	260
615	CRAIGIE PLAZA	0	0	0	260	2,588	20	166	0	2,550	0	0	5,584	177	5,761	143
616	KINGSLEY	0	100	0	500	3,298	170	1,428	160	2,067	0	10	7,733	551	8,284	324
617	PADBURY	0	0	0	0	2,138	432	261	198	0	0	0	3,029	100	3,129	148
618	BELDON	0	0	0	0	3,852	0	0	0	357	0	0	4,209	0	4,209	135
619	MULLALOO	0	0	0	70	1,937	355	298	0	800	0	0	3,460	566	4,026	108
620	HEATHRIDGE	0	0	0	150	2,487	220	576	110	0	0	0	3,543	122	3,665	153
621	EDGEWATER	0	0	0	150	1,362	100	300	0	0	0	0	1,912	190	2,102	64
622	OCEAN REEF	0	0	0	223	2,082	60	793	700	0	0	0	3,858	130	3,988	131
623	MULLALOO TAVERN	0	0	0	0	766	0	0	0	500	0	0	1,266	0	1,266	na
624	WOODVALE	0	0	0	0	2,898	220	680	0	1,704	0	0	5,502	869	6,371	198
625	MOOLANDA NORTH	0	0	0	0	252	0	0	0	0	0	0	252	320	572	na
626	WANGARA *	0	0	0	0	170	0	20	0	800	0	0	990	0	990	na
627	CONNOLLY	0	0	0	100	822	70	275	0	0	0	0	1,267	2,290	3,557	53
628	HARMAN ROAD	0	0	0	0	670	0	294	0	0	0	0	964	0	964	62
629	MOOLANDA SOUTH	0	0	0	150	540	50	83	0	0	0	0	823	0	823	44
630	MARMION	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
631	MARINE TERRACE	0	0	0	0	0	405	0	0	0	0	0	405	0	405	na
651	WALDECKS	0	0	0	0	80	221	0	0	0	0	0	301	0	301	na
653	JOONDALUP RESORT	0	0	0	0	1,088	0	750	0	0	2,812	0	4,650	0	4,650	na
661	LILBURNE ROAD	0	0	0	0	690	0	0	0	0	0	0	690	0	690	27
664	JOONDALUP SOUTH	0	0	0	25	150	300	485	310	0	0	0	1,270	892	2,162	39
665	HILLARYS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
668	HEPBURN AVENUE	0	0	0	50	240	0	0	0	0	0	0	290	1,170	1,460	na
669	GWENDOLINE DRIVE	0	0	0	180	4,555	200	1,704	75	0	0	0	6,714	570	7,284	413
671	KINROSS	0	0	0	0	670	0	160	400	0	0	0	1,230	60	1,290	40
674	CURRAMBINE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
676	SORRENTO QUAY	0	0	0	0	4,606	34	531	0	5,804	0	86	11,061	0	11,061	445
946	CURRAMBINE MARKET PL	0	0	0	70	5,310	0	165	72	0	0	0	5,617	123	5,740	97
948	JOONDALUP DRIVE	0	0	0	50	1,822	1,798	0	0	0	0	8	3,678	1,625	5,303	160
951	DUNCRAIG VILLAGE	0	0	0	75	810	0	510	75	0	0	0	1,470	0	1,470	62
8732	WOODVALE PARK	0	60	170	464	6,632	320	1,976	188	65	0	0	9,875	518	10,393	442
8733	BEAUMARIS CITY	0	0	0	70	2,733	270	1,122	200	0	0	0	4,395	464	4,859	165
8734	CANDLEWOOD	0	0	0	0	1,762	50	298	0	0	0	0	2,110	100	2,210	118
TOTAL		**0**	**445**	**1,425**	**5,475**	**168,195**	**15,154**	**50,518**	**29,741**	**52,823**	**2,812**	**695**	**327,283**	**28,122**	**355,405**	**10,862**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B12: City of Melville commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
439	BRISTOL AVE	0	0	0	0	730	0	0	0	0	0	0	730	95	825	na
440	BRENTWOOD	0	0	0	140	934	60	470	0	0	0	20	1,624	0	1,624	65
441	BATEMAN VILLAGE	0	0	0	0	1,060	0	224	0	0	0	0	1,284	65	1,349	31
442	PARRY AVE	0	0	0	80	1,883	140	273	0	0	0	0	2,376	0	2,376	97
443	FARRINGTON	0	0	0	340	3,206	220	489	50	0	0	0	4,305	0	4,305	146
444	CASTLE HILL	0	0	0	120	455	80	120	0	0	0	0	775	0	775	37
445	MYAREE	0	400	130	144	2,400	397	71	0	0	0	10	3,552	113	3,665	98
446	QUEENS RD SOUTH	0	0	0	170	745	30	63	0	0	0	0	1,008	0	1,008	33
449	REYNOLDS RD/HWY	0	0	0	50	85	50	822	0	0	0	0	1,007	0	1,007	77
518	WINTHROP	0	0	0	0	3,713	0	2,323	100	0	0	0	6,136	95	6,231	310
678	ATTADALE	0	0	0	145	1,115	133	117	0	0	0	0	1,510	0	1,510	60
TOTAL		**0**	**2,695**	**2,421**	**8,152**	**130,012**	**9,465**	**54,841**	**2,708**	**18,270**	**2,581**	**1,682**	**232,827**	**11,986**	**244,813**	**9,000**
1997																
54	ISOLATED USES-IN SW *	0	0	0	60	0	40	0	0	0	0	0	100	0	100	na
390	ALFRED COVE	0	200	1,000	180	875	1,340	20	0	450	0	0	4,065	228	4,293	51
391	PALMYRA *	0	0	800	220	540	50	75	0	0	0	0	1,685	90	1,775	31
416	PETRA ST *	0	0	220	25	8,095	550	1,998	0	0	0	400	11,288	830	12,118	436
418	McKIMMIE RD NTH	0	0	0	512	3,467	415	593	343	400	325	0	6,055	522	6,577	165
419	MELVILLE	0	0	0	778	9,169	1,178	936	250	1,150	0	0	13,461	286	13,747	485
420	STOCK RD	0	0	0	0	550	0	0	0	7,300	0	0	7,850	0	7,850	136
421	GARDEN CITY	0	100	1,712	644	46,644	260	18,553	273	5,896	0	2,015	76,097	2,870	78,967	2,506
422	BULL CREEK	0	0	0	178	15,353	211	1,186	61	901	0	0	17,890	0	17,890	591
423	KARDINYA	0	0	0	721	11,600	80	1,507	50	680	0	107	14,745	232	14,977	515
424	RISELEY ST	0	741	142	571	5,410	1,460	6,223	309	385	0	324	15,565	1,537	17,102	790
425	APPLECROSS	0	0	0	310	3,408	60	1,412	75	0	0	0	5,265	341	5,606	233
426	CANNING BRIDGE	0	698	0	1,348	4,386	456	19,774	996	4,191	1,153	30	33,032	3,530	36,562	1,402
427	HISLOP RD	0	0	139	194	1,740	970	3,568	182	155	0	0	6,948	0	6,948	386
428	NORTH LAKE RD	0	0	380	257	1,081	85	903	0	324	0	0	3,030	394	3,424	142
430	GIBSON ST	0	0	0	90	190	60	174	0	0	0	0	514	0	514	24
431	GLENELG ST	0	0	0	135	107	0	135	0	0	0	0	377	0	377	22
432	WILLAGEE	0	0	0	196	1,164	30	520	20	705	0	5	2,640	279	2,919	61
433	BAWDON	0	0	0	0	553	0	0	0	0	0	10	563	0	563	35
434	ARCHIBALD ST	0	0	0	0	354	0	218	0	0	0	0	572	0	572	50
435	HARRISON ST WLLAGEE	0	57	0	0	71	173	0	0	0	0	0	301	0	301	na
436	WEBBER ST	0	0	0	0	1,114	0	350	50	150	0	0	1,664	40	1,704	56
437	MARMION ST	0	0	0	0	1,229	0	0	0	0	0	0	1,229	0	1,229	42
438	McKIMMIE STH	0	0	0	0	255	0	0	0	0	0	0	255	0	255	na
439	BRISTOL AVE	0	0	0	0	755	0	0	0	0	0	0	755	0	755	na
440	BRENTWOOD	0	0	0	140	1,346	60	80	0	0	0	20	1,646	0	1,646	92
441	BATEMAN VILLAGE	0	0	0	0	0	0	224	0	0	0	0	224	1,052	1,276	na
442	PARRY AVE	0	0	0	144	2,360	190	662	600	3,000	0	0	6,956	88	7,044	269
443	FARRINGTON	0	0	0	260	2,988	198	2,462	490	0	0	65	6,463	413	6,876	248
444	CASTLE HILL	0	0	0	0	595	25	60	0	0	0	0	680	175	855	27
445	MYAREE	0	0	0	144	1,609	66	191	0	0	0	0	2,010	1,865	3,875	54
446	MT PLEASANT	0	0	60	170	975	30	263	0	0	0	0	1,498	0	1,498	56
449	REYNOLDS RD/HWY	0	0	0	50	85	50	780	0	0	0	0	965	82	1,047	72
518	WINTHROP	0	0	0	43	3,539	0	1,955	100	0	0	40	5,677	230	5,907	305
678	ATTADALE	0	0	0	145	1,240	133	37	0	0	0	0	1,555	0	1,555	55
966	SOMERVILLE	0	0	0	0	436	0	70	0	0	0	0	506	0	506	na
TOTAL		**0**	**1,796**	**4,453**	**7,515**	**133,283**	**8,170**	**64,929**	**3,799**	**25,687**	**1,478**	**3,016**	**254,126**	**15,084**	**269,210**	**9,391**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B13: City of Rockingham commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m^2 NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1997																
58	ISOLATED USES-OUT SW	0	0	0	0	170	0	0	0	0	0	0	170	0	170	na
100	SERVICE STATION *	0	0	0	0	90	25	0	0	0	0	0	115	0	115	na
808	ROCKINGHAM CITY	0	517	900	3,476	50,095	6,187	15,366	15,563	15,366	200	1,377	109,047	5,171	114,218	3,284
809	ROCKINGHAM BEACH	0	84	290	315	9,779	1,217	3,631	589	1,828	1,270	93	19,096	2,355	21,451	649
810	SHOALWATER	0	50	0	170	5,212	30	356	0	0	0	0	5,818	200	6,018	224
811	BAYSIDE	0	60	0	180	1,089	365	495	0	60	0	48	2,297	207	2,504	89
812	MALIBU	0	0	0	0	1,212	0	274	300	66	0	0	1,852	0	1,852	82
813	PARKIN STREET	0	0	0	0	425	186	0	100	0	0	0	711	0	711	na
814	SORAYA PLACE	0	0	0	0	150	0	0	0	0	0	0	150	0	150	na
815	WAIKIKI	0	85	120	40	1,495	138	0	0	1,300	0	0	3,178	0	3,178	93
816	WARNBRO	0	0	0	150	1,491	170	20	130	400	0	0	2,361	284	2,645	94
818	BELL	0	120	0	0	230	0	180	0	0	0	0	530	60	590	29
819	FISHER	0	0	0	0	100	0	0	0	0	0	0	100	0	100	na
820	SAFETY BAY ROAD	0	0	0	0	839	0	104	0	0	0	0	943	140	1,083	na
821	ARCADIA DRIVE	0	0	0	0	0	0	0	0	0	0	0	0	75	75	0
822	McLARTY	0	0	0	0	210	0	0	0	0	0	0	210	0	210	na
823	RAE ROAD	0	0	0	0	0	0	0	280	0	0	0	280	0	280	na
824	BENT STREET	0	0	0	0	472	0	0	0	0	0	0	472	0	472	na
825	READ ROAD	0	0	0	0	600	0	0	0	0	0	0	600	0	600	na
828	DAMPIER DRIVE	0	0	0	0	772	50	275	0	0	0	0	1,097	0	1,097	34
829	MANDURAH ROAD	0	0	0	0	150	20	0	0	0	0	0	170	0	170	na
830	SINGLETON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
831	GOLDEN BAY	0	0	0	0	100	0	0	0	0	0	0	100	0	100	na
833	COOLOONGUP	0	0	0	90	1,704	40	419	0	0	0	0	2,253	160	2,413	147
836	BALDIVIS	0	0	0	0	360	15	0	0	0	0	0	375	0	375	na
837	ENTERPRISE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
962	WARNBRO AVE	0	0	0	250	11,107	250	225	0	0	0	120	11,952	1,169	13,121	284
969	PORT KENNEDY	0	0	0	0	1,123	0	480	218	0	0	0	1,821	493	2,314	27
971	FORESHORE VILLAGE	0	0	0	0	480	0	0	45	0	0	0	525	0	525	na
TOTAL		**0**	**916**	**1,310**	**4,671**	**89,455**	**8,693**	**21,825**	**17,225**	**19,020**	**1,470**	**1,638**	**166,223**	**10,314**	**176,537**	**5,187**

** Part Complex. Balance in adjoining local government areas.*
na Not available

Figure B14: City of Stirling commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m^2 NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
313	GWELUP	0	57	0	300	4,883	195	120	0	0	0	0	5,555	0	5,555	84
314	GLENDALOUGH	0	0	0	230	1,425	30	0	0	0	0	0	1,685	330	2,015	42
315	STIRLING VILLAGE	0	0	0	120	1,468	40	350	0	0	0	0	1,978	0	1,978	82
316	FLORA TERRACE	0	0	0	400	1,607	60	616	0	2,010	0	0	4,693	690	5,383	134
317	NORTH BEACH	0	0	0	21	2,709	0	91	0	1,084	0	56	3,961	340	4,301	74
318	LYNN STREET	0	0	0	120	1,217	110	140	0	0	0	0	1,587	130	1,717	63
319	FIELDGATE SQUARE	0	0	0	40	728	0	110	0	1,300	0	0	2,178	1,870	4,048	37
320	WESTMINSTER PLAZA	0	0	0	100	2,575	50	447	0	900	0	0	4,072	280	4,352	85
328	VICTORIA ROAD	0	0	0	565	0	0	246	500	0	0	256	1,567	0	1,567	na
329	BIG ROCK	0	0	0	910	0	1,310	0	0	0	0	0	2,220	70	2,290	102
330	GREEN AVENUE	0	0	0	0	155	90	100	0	670	0	0	1,015	135	1,150	na
331	NORTHERN DISTRICTS	0	0	0	0	170	0	1,343	0	978	0	0	2,491	0	2,491	61
332	PIMLOTT STREET	0	0	0	0	672	0	0	0	0	0	0	672	40	712	na
336	HERDSMAN HOTEL	0	0	0	0	364	0	0	0	364	1,370	0	2,098	0	2,098	63
337	FLYNN STREET	0	0	0	180	2,036	0	500	0	0	0	0	2,716	0	2,716	172
340	LAWLEY STREET	0	0	0	0	245	0	0	0	0	0	0	245	0	245	na
341	POWELL STREET	0	0	0	0	0	800	0	0	0	0	0	800	0	800	na
342	BLYTHE AVENUE	0	0	0	70	240	50	0	0	0	0	0	360	0	360	na
343	HECTOR STREET	0	0	0	150	500	50	0	0	0	0	0	700	0	700	na
344	ST PETERS PLACE	0	60	0	0	220	0	0	0	0	0	0	280	0	280	na
345	CARRINGTON ST MT LAWLEY	0	0	0	0	0	0	198	0	0	0	0	198	0	198	na
348	RAILWAY PARADE	0	0	0	170	0	30	0	0	0	0	0	200	0	200	na
601	WARWICK GROVE *	0	0	0	0	0	0	150	0	0	0	0	150	0	150	na
957	CARINE GARDENS	0	0	0	0	0	0	0	0	0	150	200	350	0	350	na
8713	HONEYWELL BLVD	0	0	0	100	1,283	80	20	345	0	0	0	1,828	112	1,940	91
8714	SURREY ST	0	0	0	0	0	0	485	0	0	0	0	485	0	485	na
8726	SEGRAVE ST	0	0	0	124	0	267	0	0	0	0	0	391	0	391	na
TOTAL		**0**	**36,437**	**35,475**	**32,154**	**262,218**	**28,758**	**93,065**	**15,056**	**51,726**	**34,225**	**19,601**	**608,715**	**58,394**	**667,109**	**15,495**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m^2 NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1997																
52	ISOLATED USES-IN NW *	0	0	3,000	125	1,212	260	550	1,130	650	2,000	0	8,927	40	8,967	171
100	SERVICE STATION *	0	0	0	676	0	140	0	0	0	0	0	816	0	816	19
160	HASTINGS STREET	0	0	10	0	0	0	208	200	0	0	0	418	0	418	31
167	FRENCH STREET	0	0	0	0	170	0	0	0	0	0	0	170	175	345	na
204	MT LAWLEY *	0	75	0	0	4,039	0	4,080	1,157	1,980	0	210	11,541	2,108	13,649	488
213	BLAKE ST *	0	0	0	0	0	0	230	0	0	0	0	230	0	230	na
214	LORD ST *	0	91	275	281	500	110	1,755	950	0	0	0	3,962	639	4,601	156
215	ADAIR PDE *	0	0	0	350	1,171	300	220	0	720	0	0	2,761	1,036	3,797	54
244	BRADY ST *	0	180	381	421	1,687	30	1,156	730	0	0	0	4,585	879	5,464	149
253	HERDSMAN PARADE *	0	0	0	0	886	0	2,351	0	0	0	0	3,237	732	3,969	36
255	MANOFF ROAD	0	0	0	0	0	0	0	0	900	0	0	900	0	900	na
256	HAMILTON STREET	0	0	0	0	0	760	953	0	0	0	0	1,713	600	2,313	61
260	MIRRABOOKA SQUARE	0	470	2,867	5,413	47,183	2,415	17,761	1,602	7,349	0	12,202	97,262	9,605	106,867	2,105
261	INNALOO	0	27,355	25,297	11,808	39,387	9,665	27,071	1,202	4,289	0	2,923	148,997	6,079	155,076	3,807
262	KARRINYUP	0	42	0	388	22,809	60	2,820	180	3,734	0	225	30,258	15,934	46,192	1,074
263	NORTHLANDS	0	0	601	838	10,240	706	2,362	40	612	0	90	15,489	888	16,377	464
264	DOG SWAMP	0	0	0	416	8,536	388	1,003	0	0	0	0	10,343	1,860	12,203	441
265	NOLLAMARA	0	0	0	150	3,862	250	768	0	772	323	0	6,125	252	6,377	182
266	MAIN STREET	0	5,612	500	554	7,982	450	6,513	1,686	1,960	250	152	25,659	2,589	28,248	719
267	DIANELLA PLAZA	0	0	18	410	15,207	330	1,510	2,420	1,377	598	122	21,992	904	22,896	549
268	WALTER ROAD *	0	0	0	780	984	90	870	55	0	0	0	2,779	365	3,144	61
269	INGLEWOOD	0	869	0	946	9,011	4,350	3,380	480	2,030	0	0	21,066	1,009	22,075	497
270	THIRD AVENUE	0	356	110	90	4,793	150	820	0	300	0	0	6,619	25	6,644	102
272	SCARBOROUGH	0	0	162	695	11,659	545	1,659	0	10,447	29,144	2,900	57,211	2,619	59,830	897
273	CANARA ROAD	0	0	0	0	619	0	0	0	600	0	0	1,219	355	1,574	na
275	MICHAEL STREET	0	0	0	90	570	0	90	0	0	0	0	750	90	840	na
276	SHAKESPEARE AVENUE	0	580	0	300	505	0	411	0	0	0	0	1,796	208	2,004	25
277	HARRISON ST BALCATTA	0	130	0	150	620	0	0	0	0	0	0	900	70	970	20
278	BERYL STREET	0	0	0	0	490	0	0	0	0	0	0	490	0	490	na
279	LIGHT STREET	0	0	0	0	0	0	346	0	0	0	0	346	110	456	na
280	BAYLEY STREET	0	85	0	0	652	0	100	0	0	0	0	837	0	837	25
281	THE STRAND	0	0	0	0	530	0	0	0	120	0	0	650	0	650	na
282	BRADFORD STREET	0	0	0	0	240	90	0	0	0	0	0	330	0	330	na
284	ELSIE STREET	0	0	0	0	290	0	0	0	0	0	0	290	70	360	na
285	DUFFY ROAD	0	0	0	90	0	30	190	0	0	0	0	310	0	310	26
286	CARINE	0	0	0	0	298	0	469	26	0	0	0	793	0	793	62
288	ST BRIGIDS TCE	0	0	120	0	629	0	80	500	0	0	0	1,329	60	1,389	61
289	SHOLL AVENUE	0	0	0	0	364	0	80	0	0	0	0	444	0	444	na
290	MURIEL AVENUE	0	0	0	0	825	600	63	248	0	0	0	1,736	108	1,844	34
291	SACKVILLE TERRACE	0	0	0	100	620	50	0	0	0	0	0	770	0	770	26
292	BRIGHTON STREET	0	0	0	40	445	0	270	0	225	0	0	980	110	1,090	31
293	WOODLANDS VILLAGE	0	0	0	0	1,437	350	185	0	0	0	0	1,972	400	2,372	71
294	JONES STREET	0	0	0	120	938	30	0	0	0	0	0	1,088	40	1,128	30
295	STIRLING CENTRAL	0	0	1,560	74	12,500	0	1,559	72	0	0	79	15,844	549	16,393	259
296	TUART HILL	0	100	474	265	2,819	110	1,760	0	885	0	100	6,513	1,247	7,760	160
297	FLINDERS STREET	0	0	0	0	1,437	250	287	0	0	0	0	1,974	134	2,108	61
298	JOONDANNA	0	0	0	110	1,443	50	764	135	0	0	0	2,502	300	2,802	119
299	YOKINE	0	0	0	400	0	400	0	0	0	0	0	800	0	800	na
300	NORTH BEACH ROAD	0	0	0	125	2,255	126	24	0	250	0	0	2,780	220	3,000	125
301	COODE ST/WALTER RD *	0	0	0	100	2,594	0	0	0	0	0	0	2,694	127	2,821	133
302	SALISBURY STREET *	0	375	0	754	1,934	691	150	98	2,020	0	0	6,022	288	6,310	128
303	BENNION STREET	0	0	0	0	160	0	0	0	0	0	0	160	0	160	na
304	CONTACIO	0	0	0	0	200	0	0	0	0	0	0	200	0	200	na
305	MORRIS PLACE	0	0	0	150	3,548	280	340	1,300	2,720	0	0	8,338	285	8,623	124
306	GILDERCLIFFE STREET	0	0	0	160	1,348	1,080	1,150	0	0	0	0	3,738	246	3,984	67
307	HERBERT STREET	0	0	0	0	1,870	0	1,132	0	0	0	86	3,088	200	3,288	132
308	JOYCE STREET	0	0	0	220	1,286	100	326	0	480	390	0	2,802	340	3,142	83
309	THE DOWNS	0	0	90	135	1,380	60	108	0	0	0	0	1,773	0	1,773	92
310	DORIC STREET	0	0	0	0	992	100	75	0	0	0	0	1,167	75	1,242	57
311	CALAIS ROAD	0	0	10	130	1,275	200	0	0	0	0	0	1,615	145	1,760	62
312	McDONALD/MAIN STS	0	0	0	700	1,290	0	150	0	0	0	0	2,140	282	2,422	30

Figure B15: City of Swan commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1997																
57	ISOLATED USES-OUT NE *	0	0	0	0	0	50	20	0	0	0	0	70	0	70	na
100	SERVICE STATION *	0	0	0	285	0	195	0	0	0	0	0	480	0	480	na
679	SUMMER LAKES	0	0	0	0	370	0	430	0	0	0	0	800	159	959	49
695	THE VINES RESORT	0	0	0	0	0	0	0	0	0	6,000	0	6,000	0	6,000	85
696	MIDLAND SOUTH	0	90	515	220	1,280	470	936	0	872	1,700	40	6,123	0	6,123	278
698	BRISTILE	0	10,800	0	0	30	0	560	0	0	0	0	11,390	0	11,390	na
699	MIDLAND ROAD	0	0	0	0	341	0	0	0	0	0	0	341	0	341	na
700	MIDLAND CENTRE	0	1,488	1,744	4,508	63,027	12,416	49,433	6,660	6,302	280	2,080	147,938	12,156	160,094	5,451
701	GT EASTERN HWY *	0	2,487	381	4,563	7,111	14,694	884	250	437	0	180	30,987	790	31,777	602
702	GT NORTHERN HWY	0	0	0	190	559	150	1,199	0	0	0	0	2,098	90	2,188	57
703	MIDLAND NTH	0	0	0	0	80	50	0	0	0	0	0	130	0	130	na
704	MORRISON RD	0	0	0	0	342	0	0	0	0	0	0	342	0	342	na
705	VIVEASH	0	0	0	0	400	0	0	0	0	0	0	400	0	400	na
706	TANNER ST	0	0	1,000	364	1,054	150	0	0	240	0	0	2,808	190	2,998	34
707	OLD SWAN SHIRE	0	0	0	0	0	0	580	0	0	0	0	580	2,760	3,340	0
708	MIDDLE SWAN	0	0	0	0	520	0	0	0	0	0	0	520	50	570	na
709	WEXCOMBE	0	0	0	125	0	25	0	0	0	0	0	150	0	150	na
710	MIDVALE PLACE	0	0	80	75	230	0	0	400	200	0	0	985	85	1,070	na
712	HELEN ST	0	0	0	0	100	0	0	250	0	0	0	350	350	700	na
713	MIDVALE	0	0	0	100	970	560	0	0	400	400	0	2,430	600	3,030	49
714	DARLING RIDGE *	0	0	0	0	1,050	0	0	0	300	0	0	1,350	0	1,350	na
716	BEECHBORO	0	0	0	0	115	0	126	0	0	0	0	241	35	276	na
717	WOODBRIDGE	0	0	0	0	90	0	0	30	230	350	0	700	150	850	na
718	GUILDFORD NTH	0	140	405	362	760	859	70	100	537	250	0	3,483	340	3,823	81
719	GUILDFORD STH	0	242	0	1,665	4,720	970	614	0	3,918	1,035	0	13,164	994	14,158	177
720	QUEENS ROAD	0	0	0	0	212	0	0	0	900	0	0	1,112	272	1,384	na
721	BEVERLEY TCE	0	400	0	420	640	320	0	0	0	0	0	1,780	0	1,780	na
722	BEECHBORO VILLAGE	0	0	0	300	4,461	50	20	350	130	0	17	5,328	2,022	7,350	232
723	HAZELMERE	0	0	0	0	90	0	0	0	0	0	0	90	0	90	na
724	KOONGAMIA	0	0	0	0	541	0	0	0	0	0	0	541	0	541	na
725	BALLAJURA	0	40	0	131	2,112	310	305	0	925	0	0	3,823	335	4,158	97
726	GNANGARA RD EAST	0	0	0	0	0	0	0	0	0	0	0	0	60	60	0
728	HACKETT ST	0	0	0	0	200	0	0	0	0	0	0	200	0	200	na
732	LAKES TAVERN	0	0	0	0	225	0	0	0	225	0	0	450	0	450	na
744	E BULLSBROOK 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
745	E BULLSBROOK 2	0	0	200	590	1,168	800	260	0	660	0	225	3,903	0	3,903	76
786	GINGERS	0	400	0	100	25	25	0	0	0	0	0	550	0	550	na
787	BENARA RD CAVERSHAM	0	0	0	0	345	430	0	0	0	0	0	775	0	775	na
788	KINGFISHER AVENUE	0	0	0	30	5,266	30	931	400	0	0	0	6,657	60	6,717	171
790	SHELL	0	0	0	0	150	150	0	0	0	0	0	300	0	300	0
945	STRATTON PARK	0	0	0	0	1,734	387	240	0	0	0	0	2,361	48	2,409	60
8740	KIARA	0	0	0	70	1,721	170	0	180	0	0	0	2,141	215	2,356	85
8756	ELLENBROOK	0	0	0	0	260	0	280	0	0	0	0	540	80	620	na
TOTAL		**0**	**16,087**	**4,325**	**14,098**	**102,299**	**33,261**	**56,888**	**8,620**	**16,276**	**10,015**	**2,542**	**264,411**	**21,841**	**286,252**	**7,910**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B16: City of Wanneroo commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
650	KINGSWAY	0	0	0	0	180	0	460	0	0	0	0	640	0	640	na
652	TOPEKA PLACE	0	0	0	0	75	0	625	0	0	0	0	700	80	780	31
654	WINDSOR ROAD	0	0	0	0	0	0	0	0	0	0	0	0	150	150	0
655	RUSSELL ROAD	0	0	0	0	0	0	350	0	0	0	120	470	0	470	na
656	QUEENSWAY	0	0	0	0	0	200	0	0	0	0	0	200	0	200	na
657	NTH WANNEROO	0	0	0	0	80	0	0	0	0	0	0	80	0	80	na
658	BURNS BEACH ROAD	0	0	0	0	0	140	0	0	0	0	0	140	0	140	na
659	QUINNS ROAD	50	0	0	220	220	60	0	0	0	0	0	550	0	550	29
660	LAKE NEERABUP	0	0	0	0	244	0	0	0	0	0	0	244	0	244	na
662	OCEAN VIEW TAVERN	0	0	0	0	10	0	0	0	300	0	0	310	0	310	na
663	LANDSDALE	0	0	0	0	0	0	275	0	0	0	0	275	0	275	na
666	CRISAFULLI AVE	0	0	0	0	1,056	144	0	426	504	0	0	2,130	168	2,298	na
667	TAPPING WAY	0	0	0	80	1,449	120	75	0	0	0	0	1,724	0	1,724	47
670	GRIFFON WAY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
672	CLARKSON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
675	MINDARIE KEYS	0	0	0	0	1,363	0	115	0	296	629	0	2,403	610	3,013	114
TOTAL		**50**	**30**	**569**	**2,335**	**33,145**	**4,237**	**8,463**	**1,392**	**5,098**	**629**	**280**	**56,228**	**6,143**	**62,371**	**1,830**
1997																
100	SERVICE STATION *	0	0	0	0	0	380	0	0	0	0	0	380	0	380	na
394	TWO ROCKS	0	0	469	323	2,176	314	415	134	176	684	0	4,691	835	5,526	90
603	GIRRAWHEEN PARK	0	54	0	197	9,802	367	380	58	2,538	0	0	13,396	545	13,941	318
604	WANNEROO	0	0	26	377	8,706	330	2,588	60	2,300	0	150	14,537	653	15,190	505
608	SUMMERFIELD	0	0	0	164	4,086	20	320	180	0	0	0	4,770	961	5,731	175
626	WANGARA *	0	0	0	0	124	590	0	0	300	0	0	1,014	0	1,014	na
632	KOONDOOLA PLAZA	0	0	0	100	2,632	144	214	0	520	0	0	3,610	47	3,657	88
633	HAINSWORTH AVENUE	0	0	0	0	800	0	0	0	0	0	0	800	0	800	24
634	MARANGAROO	0	0	0	0	934	0	315	0	0	0	0	1,249	0	1,249	22
635	ALINJARRA	0	0	0	0	490	0	240	120	0	0	0	850	90	940	33
636	WILDFLOWER	0	0	0	0	0	100	0	0	0	0	0	100	20	120	na
637	LUSHGRO	0	0	0	0	0	80	0	0	0	0	0	80	0	80	na
638	YANCHEP	0	0	0	0	150	256	0	0	0	0	0	406	0	406	na
639	QUINNS	0	0	0	0	188	0	0	0	0	0	0	188	0	188	na
643	CLUB CAPRICORN	0	0	0	0	150	0	300	0	0	0	0	450	0	450	na
644	GNANGARA RD WEST	0	0	0	0	0	75	0	0	0	0	0	75	0	75	na
645	CALABRESE AVENUE	0	415	0	690	540	920	150	0	0	0	0	2,715	1,801	4,516	46
650	KINGSWAY	0	0	0	0	180	0	470	0	0	0	0	650	0	650	na
652	TOPEKA PLACE	0	0	0	0	75	0	694	0	0	0	0	769	60	829	26
656	QUEENSWAY	0	0	0	0	0	200	0	0	0	0	0	200	0	200	na
657	NTH WANNEROO	0	0	0	0	80	80	0	0	0	0	0	160	0	160	na
658	BURNS BEACH ROAD	0	0	0	0	0	140	0	0	0	0	0	140	0	140	na
659	QUINNS ROAD	0	0	0	220	220	60	0	0	0	0	0	500	0	500	31
660	LAKE NEERABUP	0	0	0	0	244	0	0	0	0	0	0	244	0	244	na
662	OCEAN VIEW TAVERN	0	0	0	0	10	0	0	0	300	0	0	310	0	310	na
663	LANDSDALE	0	0	0	0	0	0	0	0	0	0	0	0	275	275	0
666	CRISAFULLI AVE	0	0	288	0	771	576	147	234	336	0	0	2,352	1,080	3,432	79
667	TAPPING WAY	0	0	0	0	2,008	196	122	0	0	0	0	2,326	0	2,326	77
670	GRIFFON WAY	0	0	0	0	0	0	0	1,200	0	0	0	1,200	0	1,200	0
672	CLARKSON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
675	MINDARIE KEYS	0	0	0	0	1,323	0	115	0	296	629	0	2,363	610	2,973	102
947	KINGSWAY CITY	0	0	5	128	14,682	0	55	79	150	0	80	15,179	675	15,854	660
949	ALKIMOS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
950	THE BROADVIEW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
963	MERRIWA REGION	0	0	0	0	100	100	0	0	0	0	0	200	0	200	na
TOTAL		**0**	**469**	**788**	**2,199**	**50,471**	**4,928**	**6,525**	**2,065**	**6,916**	**1,313**	**230**	**75,904**	**7,652**	**83,556**	**2,462**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B17: City of Claremont commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m^2 NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1990																
52	ISOLATED USES-IN NW *	0	0	0	603	1,566	1,044	0	0	0	0	0	3,213	378	3,591	64
120	CLAREMONT T CENTRE	0	0	1,330	917	23,625	7,016	4,561	365	1,517	0	483	39,814	2,272	42,086	1,287
121	STIRLING HWY *	0	875	1,832	1,185	7,274	8,024	8,387	0	906	0	0	28,483	3,485	31,968	541
122	GRAYLANDS	0	0	100	0	1,066	80	0	0	0	0	24	1,270	65	1,335	36
123	SWANBOURNE *	0	0	0	93	1,778	100	276	0	761	0	20	3,028	0	3,028	99
TOTAL		**0**	**875**	**3,262**	**2,798**	**35,309**	**16,264**	**13,224**	**365**	**3,184**	**0**	**527**	**75,808**	**6,200**	**82,008**	**2,027**
1993																
52	ISOLATED USES-IN NW *	0	120	0	405	2,264	394	200	0	0	0	0	3,383	208	3,591	271
120	CLAREMONT T CENTRE	0	130	260	1,038	25,330	6,012	4,268	1,112	4,816	0	483	43,449	3,664	47,113	1,434
121	STIRLING HWY *	0	510	2,674	1,636	5,164	10,742	8,719	636	1,165	0	180	31,426	1,699	33,125	596
122	GRAYLANDS	0	0	0	0	586	550	75	0	0	0	24	1,235	100	1,335	40
123	SWANBOURNE *	0	0	0	93	1,778	100	36	0	761	0	20	2,788	240	3,028	119
TOTAL		**0**	**760**	**2,934**	**3,172**	**35,122**	**17,798**	**13,298**	**1,748**	**6,742**	**0**	**707**	**82,281**	**5,911**	**88,192**	**2,460**
1997																
115	CLAREMONT STH	0	120	0	0	830	300	309	0	0	0	0	1,559	0	1,559	46
120	CLAREMONT T CENTRE	0	530	132	1,005	28,237	3,718	5,744	760	7,294	0	483	47,903	2,403	50,306	1,646
121	STIRLING HWY *	0	475	1,400	2,616	5,634	10,066	7,661	636	1,365	0	350	30,203	1,889	32,092	579
122	CLAREMONT NTH	0	0	0	450	1,080	485	180	0	0	0	24	2,219	65	2,284	80
123	SWANBOURNE *	0	0	0	208	2,478	100	0	0	761	0	20	3,567	0	3,567	136
TOTAL		**0**	**1,125**	**1,532**	**4,279**	**38,259**	**14,669**	**13,894**	**1,396**	**9,420**	**0**	**877**	**85,451**	**4,357**	**89,808**	**2,487**

** Part Complex. Balance in adjoining local government area(s).*

Figure B18: Town of Cottesloe commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m^2 NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1990																
52	ISOLATED USES-IN NW *	0	0	0	50	597	0	0	0	0	0	0	647	0	647	36
100	SERVICE STATION *	0	0	0	860	0	110	0	0	0	0	0	970	0	970	na
123	SWANBOURNE *	0	0	0	0	370	0	429	75	0	0	0	874	0	874	29
129	NORTH ST EAST *	0	0	0	0	70	0	0	0	0	0	0	70	0	70	na
140	COTTESLOE T CENTRE *	0	0	200	1,687	9,983	5,733	5,693	740	606	0	135	24,777	2,140	26,917	628
141	ERIC STREET	0	0	0	24	1,085	0	0	0	2,248	3,580	0	6,937	96	7,033	76
142	COTTESLOE BEACH	0	0	0	48	912	0	0	0	1,700	83	0	2,743	0	2,743	32
143	CHAMBERLAIN STREET	0	0	0	150	1,582	45	293	0	188	0	0	2,258	150	2,408	49
TOTAL		**0**	**0**	**200**	**2,819**	**14,599**	**5,888**	**6,415**	**815**	**4,742**	**3,663**	**135**	**39,276**	**2,386**	**41,662**	**858**
1993																
52	ISOLATED USES-IN NW *	0	0	0	0	602	0	0	0	0	0	0	602	45	647	39
100	SERVICE STATION *	0	0	0	120	0	50	0	0	0	0	0	170	0	170	na
123	SWANBOURNE *	0	75	0	145	435	0	867	220	60	0	0	1,802	75	1,877	74
129	NORTH ST EAST *	0	0	0	0	70	0	0	0	0	0	0	70	0	70	na
140	COTTESLOE T CENTRE *	0	175	200	1,675	10,880	5,748	5,430	946	616	0	135	25,805	1,113	26,918	732
141	ERIC STREET	0	0	0	24	605	0	0	0	2,248	3,580	0	6,457	444	6,901	57
142	COTTESLOE BEACH	0	0	0	48	822	0	0	0	1,700	83	0	2,653	90	2,743	106
143	CHAMBERLAIN STREET	0	0	0	60	1,174	0	293	0	268	0	0	1,795	215	2,010	55
TOTAL		**0**	**250**	**200**	**2,072**	**14,588**	**5,798**	**6,590**	**1,166**	**4,892**	**3,663**	**135**	**39,354**	**1,982**	**41,336**	**1,071**
1997																
123	SWANBOURNE *	0	35	0	236	160	0	792	220	135	0	0	1,578	80	1,658	78
129	NORTH ST EAST *	0	0	0	0	70	0	0	0	0	0	0	70	0	70	na
140	COTTESLOE T CENTRE *	0	150	205	1,165	9,367	5,538	5,150	821	556	0	135	23,087	2,960	26,047	742
141	ERIC STREET	0	0	0	0	489	0	0	0	2,248	3,580	0	6,317	83	6,400	114
142	COTTESLOE BEACH	0	0	0	0	536	0	0	0	1,700	0	0	2,236	259	2,495	124
143	COTTESLOE – ISO USES	0	0	0	180	1,890	50	293	0	268	0	0	2,681	285	2,966	na
TOTAL		**0**	**185**	**205**	**1,581**	**12,512**	**5,588**	**6,235**	**1,041**	**4,907**	**3,580**	**135**	**35,969**	**3,667**	**39,636**	**1,172**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B19: Town of Mosman Park commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA) PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	EMPLOYMENT (persons) TOTAL
1990																
52	ISOLATED USES-IN NW *	0	0	0	160	680	0	0	0	0	0	0	840	0	840	31
100	SERVICE STATION *	0	0	0	804	0	155	0	0	0	0	0	959	200	1,159	na
150	JOHNSON STREET *	0	0	0	0	130	0	174	174	0	0	0	478	200	678	na
151	GLYDE STREET	0	0	0	175	1,658	80	505	300	0	0	200	2,918	663	3,581	87
152	MOSMAN HOTEL	0	0	0	76	4,106	100	150	250	1,820	0	0	6,502	0	6,502	120
153	ST LEONARDS	0	28	0	180	1,450	575	160	150	300	0	0	2,843	0	2,843	70
154	WELLINGTON STREET	0	0	0	36	860	80	46	0	0	0	58	1,080	620	1,700	35
TOTAL		**0**	**28**	**0**	**1,431**	**8,884**	**990**	**1,035**	**874**	**2,120**	**0**	**258**	**15,620**	**1,683**	**17,303**	**374**
1993																
52	ISOLATED USES-IN NW *	0	0	0	310	560	0	0	0	0	0	0	870	0	870	31
100	SERVICE STATION *	0	0	0	400	0	35	0	0	0	0	0	435	524	959	na
150	JOHNSON STREET *	0	0	0	0	286	0	170	174	0	0	0	630	0	630	na
151	GLYDE STREET	0	90	0	148	1,516	130	765	300	0	0	0	2,949	760	3,709	111
152	MOSMAN HOTEL	0	0	0	76	4,076	100	45	250	1,875	0	30	6,452	105	6,557	114
153	ST LEONARDS	0	0	0	180	1,366	575	160	150	300	0	0	2,731	112	2,843	75
154	WELLINGTON STREET	0	0	0	98	1,531	80	46	0	0	0	5	1,760	0	1,760	61
TOTAL		**0**	**90**	**0**	**1,212**	**9,335**	**920**	**1,186**	**874**	**2,175**	**0**	**35**	**15,827**	**1,501**	**17,328**	**419**
1997																
150	JOHNSON STREET *	0	0	0	0	286	0	150	150	0	0	0	586	0	586	28
151	GLYDE STREET	0	90	70	261	1,925	0	1,210	950	240	0	0	4,746	503	5,249	204
152	MOSMAN HOTEL	0	0	0	77	4,043	100	45	250	55	0	30	4,600	260	4,860	100
153	ST LEONARDS	0	0	0	180	1,216	575	160	150	300	0	0	2,581	232	2,813	78
154	MOSMAN PARK	0	0	0	848	2,801	260	46	0	0	0	5	3,960	115	4,075	115
TOTAL		**0**	**90**	**70**	**1,366**	**10,271**	**935**	**1,611**	**1,500**	**595**	**0**	**35**	**16,473**	**1,110**	**17,583**	**525**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B20: Shire of Peppermint Grove commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA) PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	EMPLOYMENT (persons) TOTAL
1990																
140	COTTESLOE TOWN CENTRE *	0	0	100	370	13,262	545	1,076	62	0	0	0	15,415	560	15,975	351
150	JOHNSON STREET *	0	0	0	0	877	0	314	0	0	0	0	1,191	1,375	2,566	45
TOTAL		**0**	**0**	**100**	**370**	**14,139**	**545**	**1,390**	**62**	**0**	**0**	**0**	**16,606**	**1,935**	**18,541**	**396**
1993																
140	COTTESLOE TOWN CENTRE *	0	0	166	370	13,432	291	969	70	0	0	0	15,298	773	16,071	397
150	JOHNSON STREET *	0	0	0	0	470	0	581	22	15	0	0	1,088	477	1,565	46
TOTAL		**0**	**0**	**166**	**370**	**13,902**	**291**	**1,550**	**92**	**15**	**0**	**0**	**16,386**	**1,250**	**17,636**	**443**
1997																
140	COTTESLOE TOWN CENTRE *	0	0	0	405	7,290	341	947	70	200	0	0	9,253	6,529	15,782	186
150	JOHNSON STREET *	0	0	28	47	858	0	502	22	0	0	0	1,457	483	1,940	58
TOTAL		**0**	**0**	**28**	**452**	**8,148**	**341**	**1,449**	**92**	**200**	**0**	**0**	**10,710**	**7,012**	**17,722**	**244**

** Part Complex. Balance in adjoining local government areas.*

Figure B21: City of Nedlands commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m^2 NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1990																
52	ISOLATED USES-IN NW *	0	0	0	999	1,114	200	0	0	0	0	0	2,313	0	2,313	59
100	SERVICE STATION *	0	0	70	200	0	50	110	0	0	0	0	430	0	430	na
106	BROADWAY *	0	0	28	52	230	0	4,208	111	0	0	0	4,629	416	5,045	124
107	COOPER STREET *	0	0	115	210	1,145	140	12,597	810	0	0	546	15,563	1,143	16,706	589
108	HAMPDEN ROAD *	0	0	300	113	2,609	0	3,670	269	150	0	0	7,111	494	7,605	251
121	STIRLING HWY *	0	0	3,992	1,532	4,795	3,223	3,130	582	937	0	500	18,691	1,500	20,191	502
128	LOCH STREET	0	0	0	0	70	0	0	0	0	0	0	70	0	70	na
129	NORTH ST EAST *	0	0	0	0	40	0	0	0	0	0	0	40	0	40	na
130	DALKEITH ROAD	0	0	0	700	2,339	4,968	1,439	333	3,400	0	0	13,179	230	13,409	235
131	NEDLANDS COUNCIL	0	0	0	0	0	0	1,100	0	0	0	0	1,100	0	1,100	111
132	STEVES	0	0	0	140	1,202	70	490	0	2,220	1,500	0	5,622	0	5,622	100
133	PRINCESS ROAD	0	50	0	140	487	143	0	0	0	0	0	820	0	820	23
134	ASQUITH STREET	0	0	0	0	844	99	0	0	0	0	5	948	0	948	24
135	FLOREAT	0	0	0	0	166	0	713	183	100	0	0	1,162	546	1,708	39
136	NORTH ST WEST	0	0	0	0	224	0	0	0	0	0	0	224	0	224	na
137	CROYDEN STREET	0	0	0	0	222	0	0	63	0	0	0	285	0	285	na
138	VILLAGE	0	0	0	431	2,228	716	896	80	800	0	0	5,151	50	5,201	190
139	WARRATAH AVENUE	0	0	0	165	971	0	200	0	0	0	0	1,336	0	1,336	26
TOTAL		**0**	**50**	**4,505**	**4,682**	**18,686**	**9,609**	**28,553**	**2,431**	**7,607**	**1,500**	**1,051**	**78,674**	**4,379**	**83,053**	**2,302**
1993																
52	ISOLATED USES-IN NW *	0	0	0	1,039	1,074	0	0	0	0	0	0	2,113	0	2,113	69
100	SERVICE STATION *	0	0	0	200	0	50	0	0	0	0	0	250	180	430	na
106	BROADWAY *	0	200	28	0	50	0	4,637	211	0	0	0	5,126	240	5,366	205
107	COOPER STREET *	0	0	45	60	1,065	120	11,459	1,072	0	0	546	14,367	2,629	16,996	572
108	HAMPDEN ROAD *	0	52	0	287	2,694	0	3,793	513	120	0	0	7,459	960	8,419	316
121	STIRLING HWY *	0	0	4,225	989	6,609	4,457	2,210	266	34	0	0	18,790	1,283	20,073	434
128	LOCH STREET	0	0	0	0	70	0	0	0	0	0	0	70	0	70	na
129	NORTH ST EAST *	0	0	0	0	40	0	0	0	0	0	0	40	0	40	na
130	DALKEITH ROAD	0	0	0	700	2,339	4,968	1,439	333	3,400	0	0	13,179	230	13,409	235
131	NEDLANDS COUNCIL	0	0	0	0	0	0	1,100	0	0	0	0	1,100	0	1,100	116
132	STEVES	0	0	0	140	1,402	80	265	0	2,020	1,500	0	5,407	0	5,407	105
133	PRINCESS ROAD	0	72	0	140	518	40	0	0	0	0	0	770	50	820	26
134	ASQUITH STREET	0	0	0	0	844	99	0	0	0	0	5	948	0	948	26
135	FLOREAT	0	0	0	0	166	0	713	183	100	0	0	1,162	546	1,708	39
136	NORTH ST WEST	0	0	0	0	164	0	60	0	0	0	0	224	0	224	na
137	CROYDEN STREET	0	0	0	0	222	0	63	0	0	0	0	285	0	285	na
138	VILLAGE	0	0	0	511	2,421	866	987	0	800	0	55	5,640	30	5,670	176
139	WARRATAH AVENUE	0	0	0	0	1,236	0	100	0	0	0	0	1,336	0	1,336	29
TOTAL		**0**	**324**	**4,298**	**4,066**	**20,914**	**10,680**	**26,826**	**2,578**	**6,474**	**1,500**	**606**	**78,266**	**6,148**	**84,414**	**2,378**
1997																
106	BROADWAY *	0	200	0	240	236	50	1,908	50	0	0	0	2,684	2,934	5,618	117
107	COOPER STREET *	0	103	45	60	1,185	120	10,808	1,802	0	0	684	14,807	2,578	17,385	567
108	HAMPDEN ROAD *	0	0	59	315	2,530	95	4,246	513	120	0	0	7,878	754	8,632	320
112	SUBIACO – ISO USES *	0	0	0	200	200	0	0	0	0	0	0	400	0	400	na
116	KARRAKATTA	0	0	0	799	138	0	0	0	0	0	0	937	0	937	na
117	TAWARRI	0	0	0	0	250	0	0	0	0	0	0	250	0	250	36
121	STIRLING HWY *	0	0	1,537	445	7,338	3,627	3,833	225	413	0	0	17,418	3,715	21,133	431
123	SWANBOURNE *	0	0	0	0	300	0	0	0	0	0	0	300	0	300	na
128	LOCH STREET	0	0	0	0	70	0	0	0	0	0	0	70	0	70	na
129	NORTH ST EAST *	0	0	0	0	40	0	0	0	0	0	0	40	0	40	na
130	DALKEITH ROAD	0	0	440	780	2,763	950	2,657	0	3,400	0	69	11,059	2,080	13,139	258
131	NEDLANDS COUNCIL	0	0	0	0	0	0	1,100	0	0	0	0	1,100	0	1,100	116
132	STEVES	0	0	0	0	1,790	30	375	0	1,910	1,500	0	5,605	0	5,605	120
133	PRINCESS ROAD	0	100	0	140	471	40	0	0	50	0	0	801	0	801	25
134	ASQUITH STREET	0	0	0	0	744	158	0	0	0	0	0	902	91	993	35
135	FLOREAT	0	0	0	100	166	0	980	91	0	0	0	1,337	279	1,616	54
136	NORTH ST WEST	0	0	0	0	260	0	60	0	0	0	0	320	0	320	na
137	CROYDEN STREET	0	0	0	0	222	0	0	0	0	0	0	222	63	285	na
138	VILLAGE	0	0	0	511	2,292	866	1,347	0	1,040	172	55	6,283	0	6,283	213
139	WARRATAH AVENUE	0	0	0	0	1,031	0	145	0	100	0	0	1,276	60	1,336	20
TOTAL		**0**	**403**	**2,081**	**3,590**	**22,026**	**5,936**	**27,459**	**2,681**	**7,033**	**1,672**	**808**	**73,689**	**12,554**	**86,243**	**2,360**

** Part Complex. Balance in adjoining local government area(s).* *na Not available*

Figure B22: Shire of Kalamunda commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1997																
57	ISOLATED USES-OUT NE *	0	0	0	100	2,125	30	168	0	0	0	15	2,438	75	2,513	27
100	SERVICE STATION *	0	0	0	550	0	360	86	0	0	0	0	996	0	996	33
750	KALAMUNDA CENTRE	0	257	20	878	14,873	3,819	5,500	376	1,729	400	480	28,332	2,041	30,373	983
751	FORRESTFIELD FORUM	0	0	0	271	10,841	212	1,624	118	450	0	53	13,569	3,611	17,180	540
752	GOOSEBERRY HILL	0	45	0	110	663	0	240	0	0	0	0	1,058	0	1,058	37
753	FORRESTFIELD	0	0	0	100	1,982	190	65	0	340	0	0	2,677	354	3,031	105
754	KALAMUNDA GLADES	0	0	0	0	1,385	60	56	0	0	0	0	1,501	0	1,501	101
755	SANDERSON	0	0	0	120	1,905	340	0	0	0	0	0	2,365	160	2,525	57
756	NEWBURN ROAD	0	0	0	0	1,185	90	90	0	0	0	0	1,365	0	1,365	44
757	LESMURDIE	0	0	0	0	670	0	0	0	0	0	15	685	180	865	27
758	HIGH WYCOMBE	0	0	0	0	965	4	0	0	0	0	0	969	0	969	25
760	MAIDA VALE	0	0	0	170	790	250	350	0	0	0	0	1,560	0	1,560	38
761	HALE ROAD	0	0	0	100	200	420	260	0	300	0	400	1,680	0	1,680	27
762	ANDERSON ROAD	0	0	398	807	940	1,360	900	0	0	0	0	4,405	230	4,635	54
763	KALAMUNDA HIGH SCHOOL	0	0	0	0	102	0	0	0	0	0	0	102	0	102	na
764	BLAMIRE ROAD	0	0	0	0	250	0	0	0	0	0	0	250	0	250	na
765	WALLISTON	0	0	0	0	160	0	0	0	0	0	0	160	0	160	na
768	HIGH WYCOMBE HOTEL	0	0	0	0	790	0	0	0	1,000	1,500	0	3,290	0	3,290	na
769	WATTLE GROVE	0	0	0	0	375	150	75	0	0	1,450	0	2,050	0	2,050	na
784	WANDILLA	0	0	0	0	1,200	600	0	450	0	0	0	2,250	0	2,250	na
785	HAWTIN RD	0	0	0	0	60	80	0	0	0	0	0	140	0	140	na
970	WITTENOOM RD	0	0	0	0	0	0	0	0	0	0	20	20	0	20	0
TOTAL		**0**	**302**	**418**	**3,206**	**41,461**	**7,965**	**9,414**	**944**	**3,819**	**3,350**	**983**	**71,862**	**6,651**	**78,513**	**2,192**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B23: Shire of Mundaring commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA) PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	EMPLOYMENT (persons) TOTAL
1997																
57	ISOLATED USES-OUT NE *	0	0	0	0	400	150	0	0	0	0	0	550	410	960	22
100	SERVICE STATION *	0	0	270	475	0	100	0	0	0	0	0	845	0	845	28
701	GT EASTERN HWY *	0	0	0	406	820	845	0	0	0	0	0	2,071	60	2,131	42
714	DARLING RIDGE *	0	0	0	150	1,122	193	90	0	0	0	0	1,555	0	1,555	60
715	SWAN VIEW	0	0	0	0	3,513	0	68	0	0	0	80	3,661	177	3,838	96
729	OLD YORK RD	0	0	0	0	190	0	0	0	0	0	0	190	0	190	na
730	DARLINGTON 1	0	0	0	0	278	0	75	0	0	0	0	353	58	411	na
731	DARLINGTON 2	0	0	0	0	152	0	0	0	78	0	60	290	0	290	na
733	GLEN FORREST 1	0	0	0	150	874	340	300	0	0	0	0	1,664	0	1,664	60
734	GLEN FORREST 2	0	0	0	0	644	0	84	0	0	0	80	808	18	826	30
735	MAHOGANY CREEK	0	0	0	0	70	0	0	0	0	0	0	70	0	70	na
736	STONEVILLE	0	0	0	0	149	100	0	0	0	0	0	249	80	329	na
737	MUNDARING	0	80	0	80	6,637	820	3,676	1,358	1,090	0	200	13,941	1,143	15,084	500
738	SAWYERS VALLEY	0	0	400	0	1,068	0	0	0	250	0	70	1,788	123	1,911	27
739	MT HELENA 1	0	0	0	0	0	0	0	0	350	0	0	350	0	350	na
740	MT HELENA 2	0	0	0	0	547	720	90	0	0	0	0	1,357	0	1,357	24
741	MT HELENA 3	0	0	0	0	300	0	0	0	0	0	0	300	0	300	na
742	PARKERVILLE 1	0	0	0	0	72	0	0	0	164	160	0	396	0	396	na
743	PARKERVILLE 2	0	0	0	0	170	5	0	0	0	0	0	175	0	175	na
746	CHIDLOW 1	0	0	0	150	840	45	0	0	0	0	0	1,035	180	1,215	35
747	CHIDLOW 2	0	90	0	0	315	0	0	120	300	0	50	875	0	875	30
749	SCOTT STREET	0	0	0	0	80	0	0	0	0	0	0	80	100	180	na
780	BINDER STREET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
781	HALIFAX PLACE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
782	OLD MAHOGANY	0	0	0	0	2,500	0	0	0	25	2,350	0	4,875	0	4,875	na
TOTAL		**0**	**170**	**670**	**1,411**	**20,741**	**3,318**	**4,383**	**1,478**	**2,257**	**2,510**	**540**	**37,478**	**2,349**	**39,827**	**1,012**

** Part Complex. Balance in adjoining local government areas.*
na Not available

Figure B24: Shire of Serpentine-Jarrahdale commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA) PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	EMPLOYMENT (persons) TOTAL
1990																
59	ISOLATED USES-OUT SE*	0	0	0	0	270	729	120	0	0	0	0	1,119	0	1,119	21
916	THOMAS RD	0	0	36	150	0	35	0	0	0	0	0	220	0	220	na
918	GEORGE RD	0	0	0	1,250	75	300	0	0	0	0	0	1,625	0	1,625	26
920	BYFORD	0	0	0	0	1,935	573	80	0	200	0	0	2,788	281	3,069	72
922	WARRINGTON RD	0	0	0	0	0	200	0	0	0	0	0	200	0	200	na
942	ATKINS STREET	0	0	0	0	407	0	0	0	320	0	2	729	0	729	na
943	SERPENTINE	0	0	0	1,052	460	0	0	0	430	0	190	2,132	260	2,392	na
944	MUNDIJONG	0	0	180	0	940	5	90	100	540	390	60	2,305	0	2,305	28
TOTAL		**0**	**0**	**215**	**2,452**	**4,087**	**1,842**	**290**	**100**	**1,490**	**390**	**252**	**11,118**	**541**	**11,659**	**181**
1993																
59	ISOLATED USES-OUT SE*	0	0	0	0	220	729	120	0	0	0	0	1,069	0	1,069	23
916	THOMAS RD	0	0	0	150	0	35	0	0	0	0	0	185	0	185	na
918	GEORGE RD	0	0	0	1,250	40	335	0	0	0	0	0	1,625	35	1,660	na
920	BYFORD	0	0	0	0	1,998	573	195	0	200	0	25	2,991	0	2,991	84
922	WARRINGTON RD	0	0	0	0	0	250	0	0	0	0	0	250	0	250	na
942	ATKINS STREET	0	0	0	0	407	300	25	0	320	0	2	1,054	0	1,054	na
943	SERPENTINE	0	0	0	1,192	400	0	0	0	600	0	190	2,382	180	2,562	na
944	MUNDIJONG	0	0	0	0	940	185	90	100	540	390	60	2,305	0	2,305	21
TOTAL		**0**	**0**	**0**	**2,592**	**4,005**	**2,407**	**430**	**100**	**1,660**	**390**	**277**	**11,861**	**215**	**12,076**	**183**
1997																
59	ISOLATED USES-OUT SE*	0	0	0	70	0	30	0	0	0	0	0	100	0	100	na
918	GEORGE RD	0	0	0	710	275	60	0	0	0	0	0	1,045	125	1,170	na
920	BYFORD	0	0	0	0	2,074	573	275	0	1,220	0	25	4,167	0	4,167	107
942	ATKINS STREET	0	0	0	0	407	300	25	0	320	0	2	1,054	0	1,054	na
943	SERPENTINE	0	0	0	1,052	400	0	0	60	430	0	0	1,942	260	2,202	na
944	MUNDIJONG	0	0	0	0	1,015	185	90	100	540	390	40	2,360	0	2,360	27
TOTAL		**0**	**0**	**0**	**1,832**	**4,171**	**1,148**	**390**	**160**	**2,510**	**390**	**67**	**10,668**	**385**	**11,053**	**191**

** Part Complex. Balance in adjoining local government areas.*
na Not available

Figure B25: City of Cambridge commercial land use

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1997																
52	ISOLATED USES-IN NW *	0	500	0	945	5,959	668	1,279	155	1,140	4,967	0	15,613	400	16,013	232
202	FITZGERALD ST	0	540	1,663	2,270	15,675	1,334	11,049	1,875	3,536	1,500	2,140	41,582	3,971	45,553	991
203	MT HAWTHORN	0	400	4,880	1,466	10,477	2,024	8,017	556	1,736	1,260	770	31,586	4,999	36,585	712
204	MT LAWLEY *	0	401	750	652	10,487	1,790	1,332	354	1,535	0	30	17,331	1,388	18,719	544
205	LEEDERVILLE	0	1,528	1,132	2,547	9,974	3,208	29,548	377	6,897	0	1,370	56,581	1,569	58,150	2,023
206	OXFORD STREET	0	0	510	50	654	350	340	0	0	0	0	1,904	695	2,599	na
212	CHARLES ST	0	2,408	6,622	1,878	3,546	2,932	2,542	50	5,014	0	280	25,272	7,850	33,122	636
213	BLAKE ST *	0	0	0	260	1,204	38	608	0	820	700	0	3,630	414	4,044	103
214	LORD ST *	0	0	0	200	475	3,750	465	200	0	0	0	5,090	840	5,930	45
215	ADAIR PDE *	0	100	150	0	134	0	320	0	185	0	0	889	153	1,042	na
226	MT HAWTHORN ISO USES	0	0	110	60	1,222	35	120	0	0	0	0	1,547	136	1,683	40
238	HIGHGATE *	0	1,093	9,312	16,680	13,927	8,900	33,584	9,980	7,699	1,000	84	102,259	13,979	116,238	2,034
239	WINDSOR ST	0	38	85	500	2,914	770	2,272	154	600	0	0	7,333	1,115	8,448	169
240	BULWER ST	0	490	0	300	765	0	310	0	0	0	0	1,865	80	1,945	48
241	BURT ST	0	0	0	316	1,672	50	700	0	0	0	50	2,788	150	2,938	40
242	NEWCASTLE ST	0	120	0	0	75	65	0	3,000	0	0	0	3,260	0	3,260	73
243	CHARLES HOTEL	0	0	0	0	600	1,368	0	0	823	600	0	3,391	186	3,577	35
244	BRADY ST *	0	0	1,185	150	800	585	0	0	0	0	0	2,720	0	2,720	86
245	RICHMOND ST	0	350	948	415	2,626	608	805	252	120	0	0	6,124	464	6,588	132
248	HAYNES STREET	0	150	354	330	695	0	0	0	0	0	0	1,529	80	1,609	24
249	SHAKESPEARE ST	0	0	0	140	1,035	0	330	0	0	0	0	1,505	0	1,505	49
252	BUXTON STREET	0	0	104	220	975	332	180	0	0	0	0	1,811	66	1,877	50
TOTAL		**0**	**8,118**	**27,805**	**29,379**	**85,891**	**28,807**	**93,801**	**16,953**	**30,105**	**10,027**	**4,724**	**335,610**	**38,535**	**374,145**	**8,109**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B26: City of Vincent commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1990																
52	ISOLATED USES-IN NW *	0	109	0	70	665	0	460	70	540	0	0	1,914	384	2,298	124
207	FLOREAT FORUM	0	0	0	277	8,551	220	1,221	45	4,155	0	60	14,529	0	14,529	547
210	ESSEX ST	0	0	177	0	912	0	155	0	480	0	0	1,724	128	1,852	54
217	OCEAN VILLAGE	0	0	0	0	1,661	0	160	0	0	0	0	1,821	458	2,279	83
218	BIRKDALE ST	0	0	0	235	1,500	205	430	0	200	0	0	2,570	551	3,121	93
219	STATION ST	0	0	119	593	1,144	0	1,103	0	625	0	0	3,584	142	3,726	75
220	WEMBLEY	0	47	0	1,528	3,659	245	1,764	0	1,425	1,375	184	10,227	0	10,227	286
221	MARLOW ST	0	100	0	365	636	40	142	50	0	0	10	1,343	50	1,393	33
228	JERSEY ST	0	0	0	0	449	0	0	0	0	0	0	449	0	449	15
229	GAMES VILLAGE	0	0	0	135	709	40	0	0	0	0	0	884	0	884	37
235	NANSON ST	0	0	0	500	1,203	120	254	0	0	0	0	2,077	0	2,077	29
236	SOUTHPORT	0	2,625	11,864	3,595	3,795	1,245	10,844	1,384	38	0	543	35,933	4,667	40,600	928
237	CAMBRIDGE ST	0	1,806	3,840	3,353	5,526	3,900	6,388	200	200	0	130	25,343	1,867	27,210	458
246	HARBOURNE ST	0	0	130	200	1,363	340	606	460	0	0	0	3,099	254	3,353	55
247	LAKE MONGER	0	309	1,110	325	618	120	1,679	0	0	0	250	4,411	0	4,411	161
253	HERDSMAN PARADE *	0	2,883	175	1,454	424	240	926	31	760	0	0	6,893	775	7,668	171
357	SALVADO RD/ HARBOURNE ST	0	0	238	0	0	0	1,947	0	0	0	0	2,185	50	2,235	48
TOTAL		**0**	**7,879**	**17,653**	**12,630**	**32,815**	**6,715**	**28,079**	**2,240**	**8,423**	**1,375**	**1,177**	**118,986**	**9,326**	**128,312**	**3,197**
1993																
52	ISOLATED USES-IN NW *	0	109	0	70	905	0	524	0	540	0	0	2,148	150	2,298	133
104	JOLIMONT *	0	0	0	0	0	0	0	0	200	0	0	200	0	200	0
207	FLOREAT FORUM	0	0	0	277	8,819	283	1,157	74	4,155	0	60	14,825	0	14,825	584
210	ESSEX ST	0	0	177	0	1,162	0	60	30	480	0	0	1,909	0	1,909	53
217	OCEAN VILLAGE	0	0	0	0	1,661	0	160	0	0	0	0	1,821	458	2,279	83
218	BIRKDALE ST	0	0	0	50	1,661	205	1,232	170	200	0	0	3,518	100	3,618	141
219	STATION ST	0	0	0	593	1,631	0	828	0	625	0	0	3,677	0	3,677	52
220	WEMBLEY	0	197	0	1,451	4,404	245	2,148	0	1,425	1,375	80	11,325	224	11,549	376
221	MARLOW ST	0	0	0	465	431	40	255	50	0	0	10	1,251	142	1,393	47
228	JERSEY ST	0	0	0	0	196	248	0	0	0	0	0	444	100	544	14
229	GAMES VILLAGE	0	0	0	135	969	40	60	0	0	0	0	1,204	0	1,204	75
235	NANSON ST	0	0	0	500	1,155	120	254	0	0	0	0	2,029	48	2,077	29
236	SOUTHPORT	0	4,249	11,537	3,388	4,929	1,185	11,210	150	340	0	146	37,134	3,928	41,062	888
237	CAMBRIDGE ST	0	1,719	5,052	2,988	4,481	2,970	8,038	307	20	0	130	25,705	2,094	27,799	494
246	HARBOURNE ST	0	0	240	350	1,268	340	500	460	0	0	0	3,158	195	3,353	71
247	LAKE MONGER	0	364	910	125	400	120	1,955	0	0	0	250	4,124	170	4,294	112
253	HERDSMAN PARADE *	0	3,083	1,150	236	424	0	1,448	0	310	0	0	6,651	1,650	8,301	88
357	SALVADO RD/ HARBOURNE ST	0	0	0	187	0	0	1,759	200	0	0	0	2,146	238	2,384	88
TOTAL		**0**	**9,721**	**19,066**	**10,815**	**34,496**	**5,796**	**31,588**	**1,441**	**8,295**	**1,375**	**676**	**123,269**	**9,497**	**132,766**	**3,328**
1997																
52	ISOLATED USES-IN NW *	0	109	0	70	835	0	530	0	540	0	0	2,084	214	2,298	109
104	JOLIMONT *	0	0	0	0	0	0	0	1,948	200	0	0	2,148	0	2,148	73
207	FLOREAT FORUM	0	0	0	127	9,078	177	1,197	74	3,705	0	153	14,511	234	14,745	739
210	ESSEX ST	0	0	353	0	951	0	85	30	480	0	0	1,899	100	1,999	46
217	OCEAN VILLAGE	0	30	0	0	2,063	20	315	0	0	0	0	2,428	463	2,891	96
218	BIRKDALE ST	0	0	0	50	1,711	205	1,481	70	0	0	0	3,517	63	3,580	138
219	STATION ST	0	0	90	218	1,119	0	948	0	625	0	0	3,000	312	3,312	52
220	WEMBLEY	0	197	0	791	3,388	145	2,069	0	1,375	1,375	157	9,497	1,412	10,909	336
221	MARLOW ST	0	50	20	315	611	140	152	0	0	0	10	1,298	145	1,443	44
228	JERSEY ST	0	0	0	0	281	0	0	0	0	0	0	281	232	513	10
229	GAMES VILLAGE	0	0	0	135	1,203	40	90	0	0	0	0	1,468	27	1,495	68
235	NANSON ST	0	0	0	500	1,154	120	254	0	0	0	0	2,028	0	2,028	32
236	SOUTHPORT	0	4,019	9,587	5,158	4,679	1,590	13,355	0	528	0	146	39,062	1,732	40,794	751
237	CAMBRIDGE ST	0	2,029	4,657	2,756	5,770	3,450	6,753	307	220	0	130	26,072	1,291	27,363	472
246	HARBOURNE ST	0	85	110	350	1,265	340	620	460	0	0	0	3,230	123	3,353	81
247	LAKE MONGER	0	210	1,010	125	220	120	3,251	0	0	0	250	5,186	0	5,186	169
253	HERDSMAN PARADE *	0	1,897	1,850	736	424	0	576	0	180	0	0	5,663	3,329	8,992	103
357	SALVADO RD/ HARBOURNE ST	0	0	0	187	0	0	1,934	250	0	0	0	2,371	320	2,691	100
TOTAL		**0**	**8,626**	**17,677**	**11,518**	**34,752**	**6,347**	**33,610**	**3,139**	**7,853**	**1,375**	**846**	**125,743**	**9,997**	**135,740**	**3,419**

* *Part Complex. Balance in adjoining local government area(s).*

Figure B27: City of Perth commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/PROCESSING/FABRICATION	STORAGE/DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/BUSINESS	HEALTH/WELFARE/COMMUNITY SERVICES	ENTERTAINMENT/RECREATIONAL/CULTURAL	RESIDENTIAL	UTILITIES/COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1990																
1	CITY 1	0	4,051	23,452	9,298	29,984	4,044	19,501	5,880	16,101	4,317	1,533	118,161	9,609	127,770	3,482
2	CITY 2	0	4,039	23,014	4,698	40,985	7,405	206,262	9,492	14,158	33,261	2,337	345,651	59,314	404,965	11,626
3	CITY 3	0	530	160	901	1,299	0	151,909	1,124	2,654	19,170	317	178,064	32,272	210,336	7,400
4	CITY 4	0	20,854	2,857	4,024	14,458	3,051	39,846	43,345	62,491	7,170	28,352	226,448	20,792	247,240	5,956
5	CITY 5	0	3,018	17,863	593	136,084	504	254,271	218,551	33,555	49,169	15,675	729,283	97,407	826,690	21,313
6	CITY 6	0	386	1,003	277	3,744	0	118,752	14,104	10,005	4,260	1,313	153,844	30,199	184,043	6,158
7	CITY 7	0	9,445	12,917	2,102	2,728	3,942	77,561	7,029	810	1,600	200	118,334	7,103	125,437	4,453
8	CITY 8	0	8,918	5,522	3,803	5,807	5,134	97,893	19,303	2,402	16,264	7,627	172,673	14,050	186,723	5,866
9	CITY 9	0	66	750	1,921	5,874	155	80,646	4,479	9,072	77,463	15,950	196,376	13,396	209,772	5,164
10	CITY 10	0	0	42	0	3,752	0	11,252	420	1,615	4,560	104	21,745	0	21,745	1,003
11	CITY 11	0	0	0	4,700	0	0	12,166	13,444	2,988	3,000	1,875	38,173	0	38,173	2,439
12	CITY 12	0	0	0	0	1,417	900	27,128	0	920	0	0	30,365	0	30,365	1,175
165	EAST PERTH	0	0	0	100	2,080	55	0	0	0	0	0	2,235	0	2,235	na
216	WEST PERTH	0	8,716	11,211	8,747	31,529	11,384	277,238	23,656	10,372	7,649	9,694	400,196	77,788	477,984	14,649
238	HIGHGATE *	0	1,275	1,650	4,937	6,506	3,625	2,790	1,623	2,190	2,230	0	26,826	1,453	28,279	544
251	MOUNTS BAY RD	0	0	0	0	0	0	0	0	0	2,480	0	2,480	100	2,580	na
TOTAL		**0**	**61,298**	**100,441**	**46,101**	**286,247**	**40,199**	**1,377,215**	**362,450**	**169,333**	**232,593**	**84,977**	**2,760,854**	**363,483**	**3,124,337**	**91,281**
1993																
1	CITY 1	0	3,141	19,862	6,253	33,339	1,545	39,987	6,892	18,533	2,565	1,069	133,186	24,298	157,484	3,957
2	CITY 2	0	3,465	22,104	4,082	40,074	7,446	216,125	9,077	16,430	31,557	2,162	352,522	200,245	552,767	9,858
3	CITY 3	0	400	108	1,270	1,754	90	159,792	1,279	3,352	18,970	594	187,609	91,646	279,255	6,390
4	CITY 4	0	21,879	3,104	3,994	16,854	1,747	38,258	57,284	64,072	4,970	23,475	235,637	14,414	250,051	5,984
5	CITY 5	0	3,260	19,450	2,134	134,066	162	245,329	202,397	34,349	44,903	9,106	695,156	128,754	823,910	20,160
6	CITY 6	0	639	3,993	122	3,840	0	127,058	13,523	8,396	3,890	230	161,691	86,341	248,032	5,341
7	CITY 7	0	9,967	8,549	3,062	3,348	3,162	81,615	5,007	670	1,600	709	117,689	8,789	126,478	4,080
8	CITY 8	0	2,030	2,425	4,557	5,242	3,435	91,837	16,912	3,911	14,864	3,626	148,839	37,022	185,861	5,210
9	CITY 9	0	33	217	1,360	4,556	30	54,633	5,428	8,758	78,560	15,742	169,317	40,510	209,827	4,103
10	CITY 10	0	0	42	0	4,492	0	10,750	160	1,615	4,590	104	21,753	0	21,753	1,042
11	CITY 11	0	0	0	4,700	0	0	12,166	13,444	2,988	3,000	275	36,573	1,600	38,173	1,848
12	CITY 12	0	0	30	0	1,897	900	26,498	0	920	0	0	30,245	0	30,245	1,457
165	EAST PERTH	0	0	0	0	1,500	0	0	0	0	0	0	1,500	0	1,500	na
216	WEST PERTH	0	9,549	9,878	13,167	33,732	12,171	294,096	15,978	13,227	9,275	11,758	422,831	75,155	497,986	13,783
238	HIGHGATE *	0	1,225	2,490	4,867	5,941	3,605	2,500	1,685	2,146	2,330	0	26,789	1,847	28,636	527
251	MOUNTS BAY RD	0	0	0	0	0	0	0	0	0	2,480	0	2,480	0	2,480	na
TOTAL		**0**	**55,588**	**92,252**	**49,568**	**290,635**	**34,293**	**1,400,644**	**349,066**	**179,367**	**223,554**	**68,850**	**2,743,817**	**710,621**	**3,454,438**	**83,760**
1997																
1	CITY 1	0	9,028	11,637	8,584	34,323	2,340	43,726	5,846	19,665	2,565	539	138,253	19,740	157,993	3,948
2	CITY 2	0	3,122	14,096	4,503	44,116	7,841	317,845	7,712	18,859	42,897	5,514	466,505	91,616	558,121	14,444
3	CITY 3	0	1,315	729	1,876	3,331	90	180,370	1,523	3,306	19,353	3,438	215,331	66,591	281,922	8,173
4	CITY 4	0	21,285	5,356	5,201	14,231	1,547	66,257	57,733	44,550	2,670	24,440	243,270	13,808	257,078	5,825
5	CITY 5	0	3,546	20,905	2,426	142,729	97	240,391	190,664	31,134	45,135	7,777	684,804	146,498	831,302	20,635
6	CITY 6	0	613	4,010	157	5,230	25	136,966	12,250	7,174	4,290	479	171,194	77,620	248,814	5,573
7	CITY 7	0	6,572	8,096	2,654	4,136	1,052	85,421	6,939	400	1,600	849	117,719	9,380	127,099	3,809
8	CITY 8	0	2,061	4,178	4,273	7,281	2,801	88,103	16,822	9,107	14,492	4,099	153,217	31,202	184,419	4,259
9	CITY 9	0	45	114	1,616	4,612	30	61,313	3,485	9,507	78,294	15,650	174,666	35,000	209,666	3,870
10	CITY 10	0	0	42	0	5,502	0	12,580	410	1,615	2,740	104	22,993	0	22,993	900
11	CITY 11	0	0	0	4,700	0	0	12,166	13,444	2,988	3,000	275	36,573	1,600	38,173	1,693
12	CITY 12	0	0	30	0	1,360	758	25,118	0	920	0	0	28,186	1,781	29,967	1,274
13	CITY 13	0	6,975	7,453	5,309	1,257	1,490	1,820	720	200	2,870	1,050	29,144	17,633	46,777	489
216	WEST PERTH	0	7,067	12,814	13,238	32,694	8,908	324,388	12,897	12,749	7,132	6,739	438,626	49,832	488,458	14,503
238	HIGHGATE *	0	610	1,540	2,332	3,372	1,120	2,172	1,310	990	1,195	0	14,641	5,139	19,780	na
251	MOUNTS BAY RD	0	0	0	0	0	0	0	0	0	2,480	0	2,480	0	2,480	na
TOTAL		**0**	**62,239**	**91,000**	**56,869**	**304,174**	**28,099**	**1,598,636**	**331,755**	**163,164**	**230,713**	**70,953**	**2,937,602**	**567,440**	**3,505,042**	**89,768**

** Part Complex. Balance in adjoining local government area(s).*
na Not available

Figure B28: City of Kwinana commercial land use data

COMPLEX NUMBER	COMPLEX NAME	FLOORSPACE (m² NLA)														EMPLOYMENT (persons)
		PRIMARY/RURAL	MANUFACTURING/ PROCESSING/ FABRICATION	STORAGE/ DISTRIBUTION	SERVICE INDUSTRY	SHOP/RETAIL	OTHER RETAIL	OFFICE/ BUSINESS	HEALTH/WELFARE/ COMMUNITY SERVICES	ENTERTAINMENT/ RECREATIONAL/ CULTURAL	RESIDENTIAL	UTILITIES/ COMMUNICATIONS	TOTAL OCCUPIED	VACANT FLOOR AREA	TOTAL	TOTAL
1990																
58	ISOLATED USES-OUT SW	0	0	0	0	450	186	0	0	250	0	0	886	0	886	na
801	KWINANA CENTRE	0	0	0	300	16,452	1,284	3,627	555	3,720	400	468	26,806	1,866	28,672	628
802	PACE ROAD	0	0	0	100	3,362	80	300	0	0	0	0	3,842	858	4,700	90
803	ORELIA	0	0	0	150	815	75	70	250	0	0	0	1,360	0	1,360	55
804	MEDINA AVENUE	0	0	0	90	0	90	0	0	0	0	0	180	0	180	na
805	SUMMERTON	0	0	0	120	444	0	372	0	0	0	0	936	0	936	34
806	CALISTA AVENUE	0	0	0	230	249	30	0	0	0	0	0	509	0	509	22
832	PARMELIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
834	WEST LEDA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL		**0**	**0**	**0**	**990**	**21,772**	**1,745**	**4,369**	**805**	**3,970**	**400**	**468**	**34,519**	**2,724**	**37,243**	**845**
1993																
58	ISOLATED USES-OUT SW	0	0	0	0	800	186	150	435	570	0	0	2,141	0	2,141	46
801	KWINANA CENTRE	0	0	0	480	16,149	1,414	4,329	685	5,380	400	72	28,909	3,327	32,236	934
802	PACE ROAD	0	0	0	100	3,572	80	290	358	1,992	0	0	6,392	640	7,032	158
803	ORELIA	0	0	0	150	810	75	0	250	0	0	0	1,285	70	1,355	30
804	MEDINA AVENUE	0	0	0	90	0	90	0	0	0	0	0	180	0	180	na
805	SUMMERTON	0	0	0	120	444	0	480	0	0	0	0	1,044	92	1,136	38
806	CALISTA AVENUE	0	0	0	230	153	30	0	0	300	0	0	713	96	809	na
832	PARMELIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL		**0**	**0**	**0**	**1,170**	**21,928**	**1,875**	**5,249**	**1,728**	**8,242**	**400**	**72**	**40,664**	**4,225**	**44,889**	**1,226**
1997																
801	KWINANA CENTRE	0	0	0	480	16,668	1,114	4,544	3,747	6,014	400	150	33,117	2,427	35,544	1,100
802	PACE ROAD	0	0	0	100	1,170	80	270	398	1,992	0	0	4,010	1,567	5,577	103
803	ORELIA	0	0	0	150	620	135	0	0	0	0	0	905	200	1,105	25
804	MEDINA AVENUE	0	0	0	90	0	90	0	0	0	0	0	180	0	180	na
805	SUMMERTON	0	0	0	250	360	0	460	0	0	0	0	1,070	0	1,070	26
806	CALISTA AVENUE	0	0	0	150	249	0	0	0	0	0	0	399	110	509	na
832	PARMELIA	0	0	0	0	370	0	0	0	0	0	0	370	687	1,057	na
835	CASUARINA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
838	LEDA	0	0	0	0	2,947	140	0	0	0	0	0	3,087	400	3,487	55
TOTAL		**0**	**0**	**0**	**1,220**	**22,384**	**1,559**	**5,274**	**4,145**	**8,006**	**400**	**150**	**43,138**	**5,391**	**48,529**	**1,334**

** Part Complex. Balance in adjoining local government area(s).*
na Not available