WP3 – Transport and Mobility Analysis

D.3.1. Transport Base Year Report Nottingham

October 2015

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Transport Base Year Report Nottingham

Work Package 3. Transport and Mobility Analysis

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Executive Summary	
This report presents the results of the Baseline Scenario of the transport model that has been developed in the framework of the INSMART project for the city of Nottingham.	
Keywords	Transport scenarios




BASE YEAR REPORT - NOTTINGHAM

INSMART – INTEGRATIVE SMART CITY PLANNING

BASE YEAR REPORT - NOTTINGHAM

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1. INTRODUCTION

1.1 Project Overview

1.1.1 InSmart is a three year, European funded project which involves four European Cities working in partnership towards a sustainable energy future. The primary objective of the project is to develop sustainable energy action plans for each partner city.

1.1.2 The four cities are;

- Cesena, Italy;
- Evora, Portugal;
- Nottingham, UK; and
- Trikala, Greece.

1.1.3 A mix of sustainable energy measures to improve the energy efficiency of each city will be identified through the use of a variety of tools and approaches. This will cover a wide range of sectors from the residential and transport sectors, to street lighting and waste collection.

1.1.4 SYSTRA's role within the project is to identify, test and report on a series of land use and transport based strategies aimed at reducing the transport-related energy usage and carbon generation of each city.

1.1.5 The initial task is to calculate the current energy usage and carbon emissions generated by each city. The impact of the forecast strategies can then be obtained by a comparison with the base figures.

1.2 Nottingham

1.2.1 This report covers the city of Nottingham in central England.

1.2.2 The city has been split into 14 zones, as shown in Figure 1. In addition the model has a 15th zone covering the area external to the 14 internal zones – allowing for travel to and from the city.

1.2.3 The city has also been split into 5 Area Types representing different areas of the city. These are;

- City Centre;
- Edge of City Centre;
- Sub0Urban areas;
- Rural/Outside City; and
- External

1.2.4 Some inputs, such as vehicle speeds, are at this more aggregate level of detail. The Area Type allocation is shown in Figure 2

1.2.5 .

1.3 Report Structure

1.3.1 The report is split into four sections;

- Executive Summary/Conclusions – the key aspects of the Base Year model outputs;
- Inputs – covering all the city-specific inputs;
- Calibration – details of model calibration to observed mode share and trip length information; and
- Outputs – details of demand movements, energy consumption and emissions.

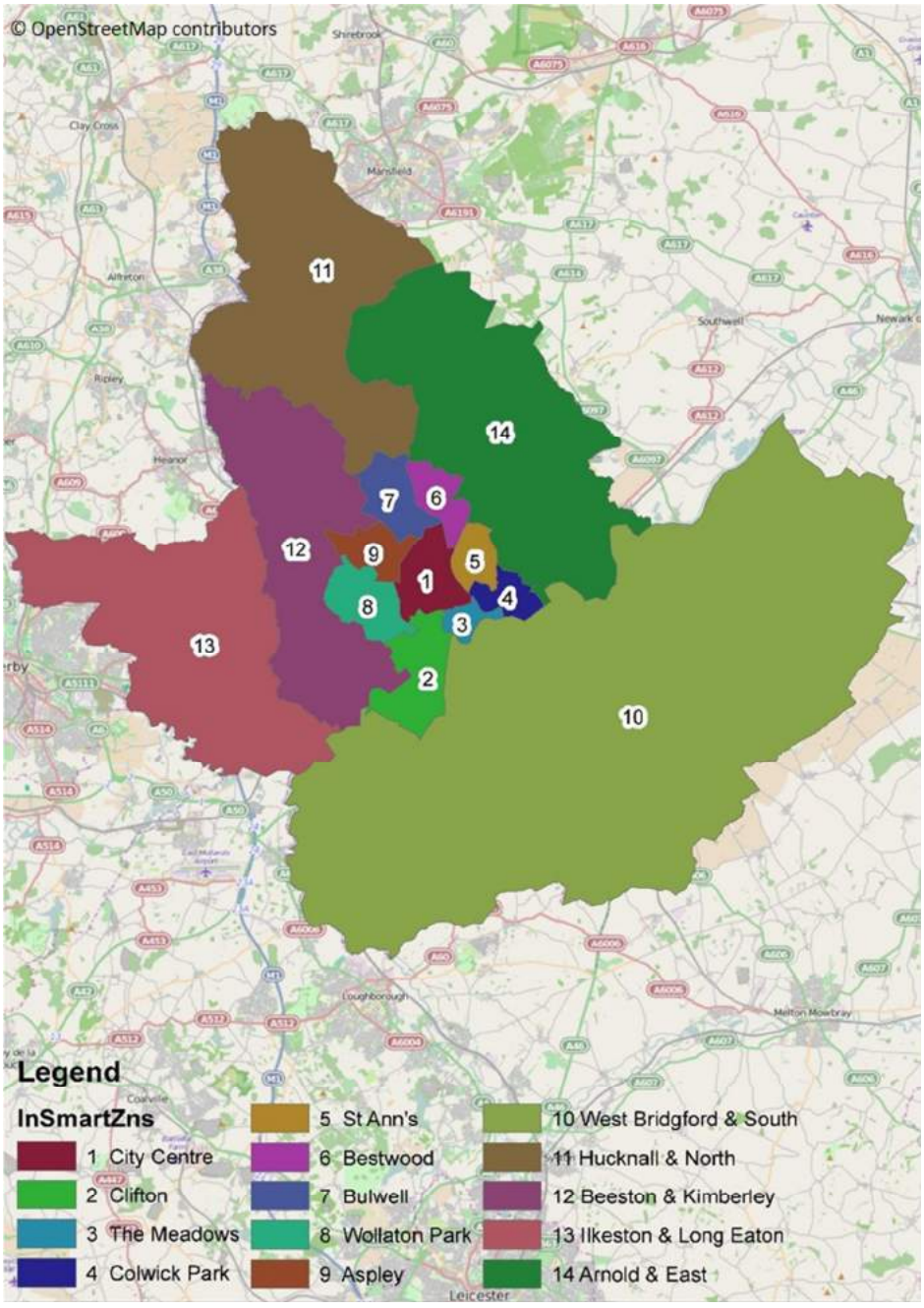

Figure 1. Nottingham Zoning System

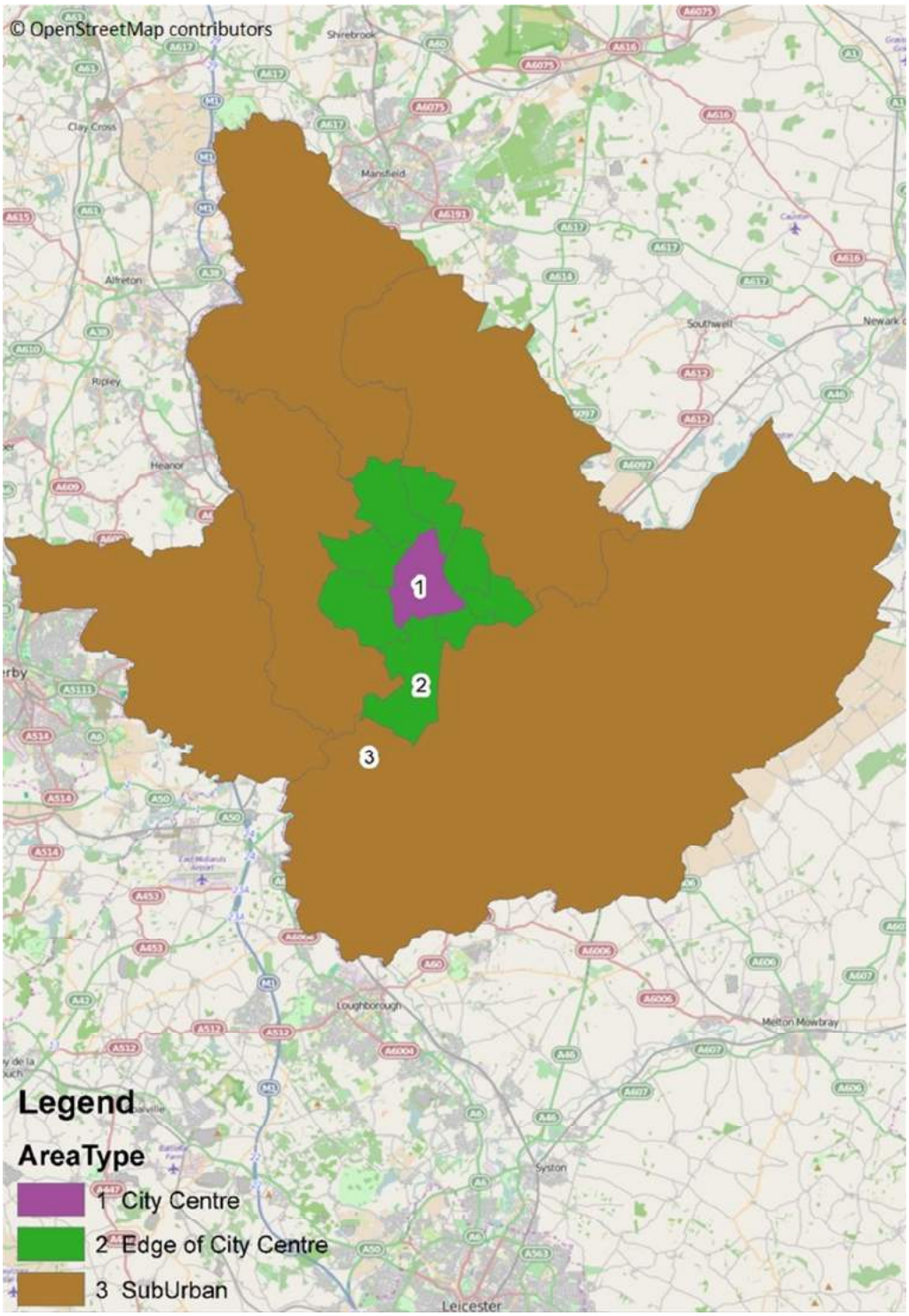

Figure 2. Nottingham Area Types

2. EXECUTIVE SUMMARY/CONCLUSIONS

2.1 Introduction

2.1.1 This section of the report aims to summarise the key aspects of the model outputs from the base year model run. They can be split into three different types of outputs:

- Demand Outputs;
- Energy Consumption Outputs; and
- Emissions Outputs.

2.1.2 A more detailed analysis of these outputs is presented in the main outputs section.

2.2 Demand Outputs

2.2.1 The total person demand in Nottingham is 4,087,072, which using average city-specific vehicle occupancies, equates to around 2,580,893 vehicles. This is on average 3.8 trips per person, with an average distance of around 7km. Figure 3 shows the number of vehicles broken down by type, showing that Petrol Cars make up more than half the total vehicle demand.

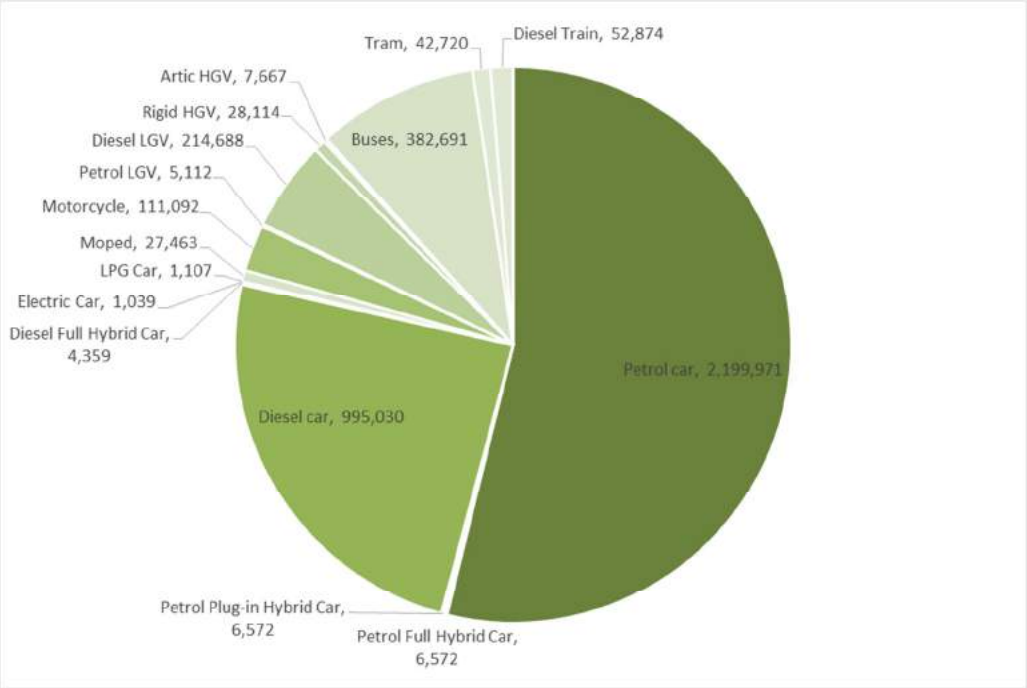

Figure 3. Demand By Vehicle Type

2.3 Energy Consumption Outputs

2.3.1 Table 1 presents a summary of the total energy used by transport within Nottingham. The total daily value across all modes, vehicle types, purposes and zones is **152,225,519 MJ**, which is around 142MJ per person, per day.

2.3.2 It can be seen that almost all of the total energy used by transport in Nottingham can be attributed to cars, which represent roughly nine tenths of the total demand.

Table 1. **Energy Usage Summary**

NO	TOTAL	CARS	BIKES	GOODS	BUSES	TRAMS	TRAINS
Total Energy (MJ)	**152,225,519**	**123,142,621**	**4,779,278**	**22,311,805**	**1,640,271**	**-**	**351,543**
Population	1,068,955						
Energy Per Person (MJ)	142.4	115.2	4.5	20.9	1.5	-	0.3
Demand (Persons)	4,087,072	3,214,651	138,554	255,581	382,691	42,720	52,874
Energy Per Trip (MJ)	37.2	38.3	34.5	87.3	4.3	-	6.6
Trips Per Person	3.8	3.0	0.1	0.2	0.4	0.0	0.05
Actual Vehicles	810,569	714,481	44,169	42,618	8,398	408	495
Energy Per Vehicle (MJ)	187.8	172.4	108.2	523.5	195.3	-	710.2
Vehicles Per Person	0.76	0.67	0.04	0.04	0.01	0.00	0.000

2.3.3 Figure 4 shows the energy consumption aggregated to the zone the demand originates in. It can be seen that zones furthest from the city centre (where the highest numbers of attractions are), often have a high energy usage due to the larger trip lengths. Whereas zones closer to the centre, often have a low energy usage from the shorter trip lengths. The exception to this is the city centre zone itself which has a large number of trips originating within it, travelling out to other zones.

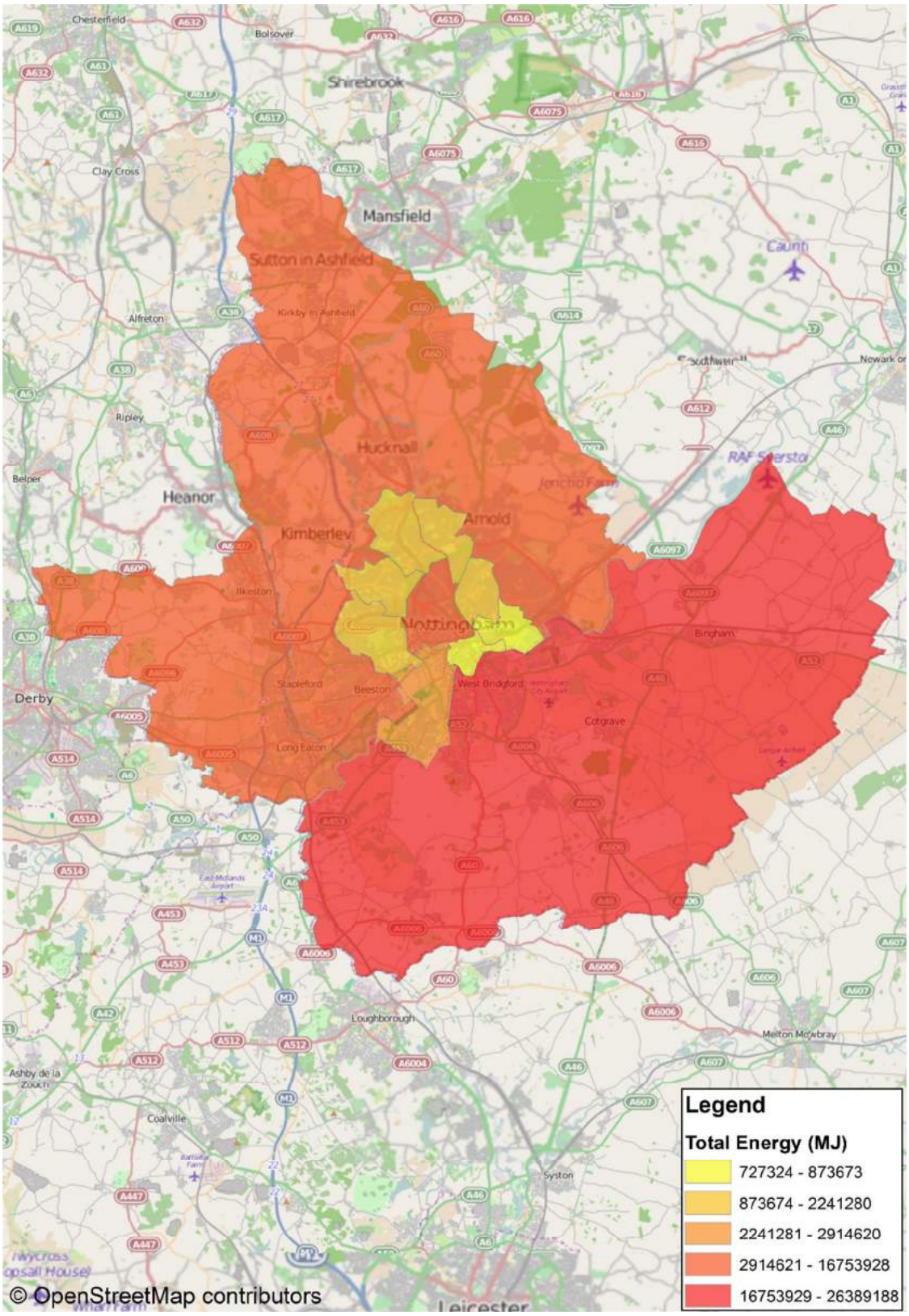

Figure 4. Total Energy (MJ) Per Origin Zone

2.4 Emissions Outputs

2.4.1 The model also reports the following emissions;

- Nitrous Oxides;
- Particulate Matter (PM10s);
- Hydro Carbons;
- Carbon Monoxide; and
- Carbon Dioxide.

2.4.2 Figure 5 demonstrates each of the emission types and the contribution each vehicle type has upon each emission. It can be seen that the splits here are very different depending on the emission type. Mopeds and Motorbikes are responsible for most of the Hydro-Carbons and Carbon Monoxide emitted despite being only a small percentage of the total demand. Petrol and Diesel cars can be seen to be responsible for the majority of the other emission types.

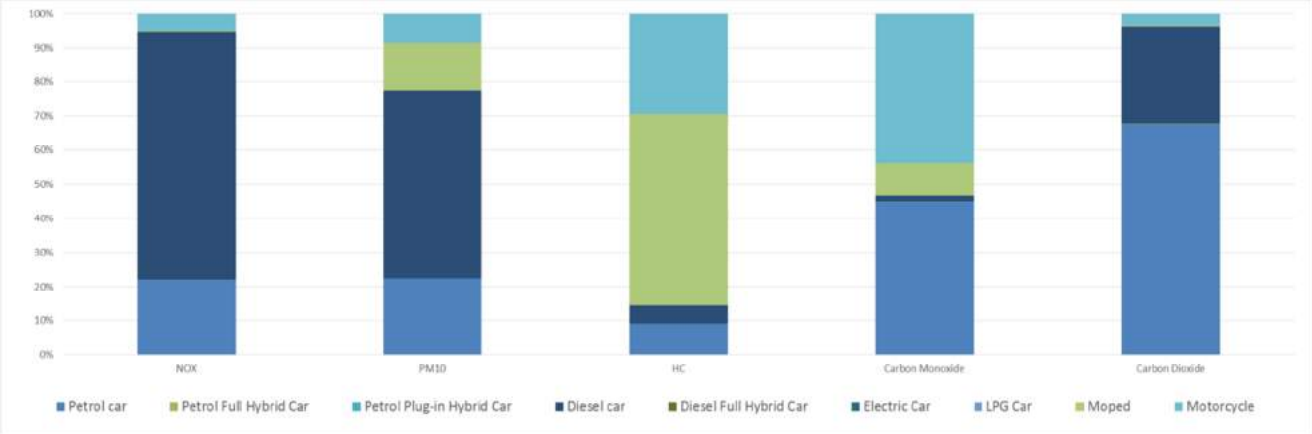

Figure 5. Emissions by Vehicle Type

3. INPUTS

3.1 Introduction

3.1.1 The inputs to the model can be broken down into three sets;

- Model specific inputs such as zoning, distances, public transport services, land use;
- Inputs common to all models such as trip purposes, vehicle types, modes etc;
- Parameters for the energy and emissions calculations and for the various transport choices (mode, destination, route).

3.1.2 This report covers only the first set – model specific inputs. In the following sections information is given on the main model-specific inputs and their sources. Inputs included are;

- Trip Ends – replacing the Land Use inputs in the other cities;
- Public Transport Routes;
- Distances;
- Speeds;
- Purpose Splits;
- Vehicle Type Splits;
- Public Transport Fares;
- Parking Charges; and
- Internal/External Demand splits.

3.2 Trip Ends

3.2.1 Trips ends are used in the Nottingham model to replace the effects provided by the land use data used in the models for the other city's models. The trip end values used for Nottingham in this model have been derived from a larger and more detailed multi-modal transport model of Nottingham.

3.2.2 Due to the nature of the data, the results subsequently only provide two trip purposes; Employment and Other. As such, there is no requirement for Purpose Splits to be used, as for the models associated with the other cities. Table 2 illustrates the trip end productions and attractions for highway and PT and goods vehicles in the Nottingham model.

Table 2. **Trip Ends – Attractions and Productions**

	HIGHWAY & PT TRIP ENDS		GOODS TRIP ENDS
ZONE ID	PRODUCTIONS	ATTRACTIONS	
1	396,517	625,928	27,802
2	136,478	168,893	13,327
3	46,535	66,779	9,433
4	44,441	41,883	4,528
5	101,159	108,984	7,004
6	102,224	82,693	3,389
7	123,026	102,910	6,535
8	93,765	92,807	8,541
9	109,204	73,111	4,873
10	411,970	326,859	24,209
11	288,715	282,075	6,735
12	382,281	356,590	27,442
13	230,795	215,011	14,265
14	457,323	379,913	28,493

3.3 Distances

3.3.1 The model calculates average travel times between zones using the average zone-zone distance and speeds. These distances have been obtained via an online routing service, choosing the most common route between the centre of each zone. The public transport distances follow the bus and rail service routes.

3.3.2 Figure 6 shows the Highway routes used, with the route between zones 1 and 10 highlighted as an example. For the highway all movements are possible between all origin-destination combinations. As the Public transport distances have to follow Public Transport routes there are some movements where travel is not possible, and so no distance exists.

3.3.3 Distances to the external zone are taken as the average distance from the larger multi-modal model to locations outside the study area.

3.3.4 Table 3 to Table 6 show the input distance matrices for highway, bus, rail and tram respectively.

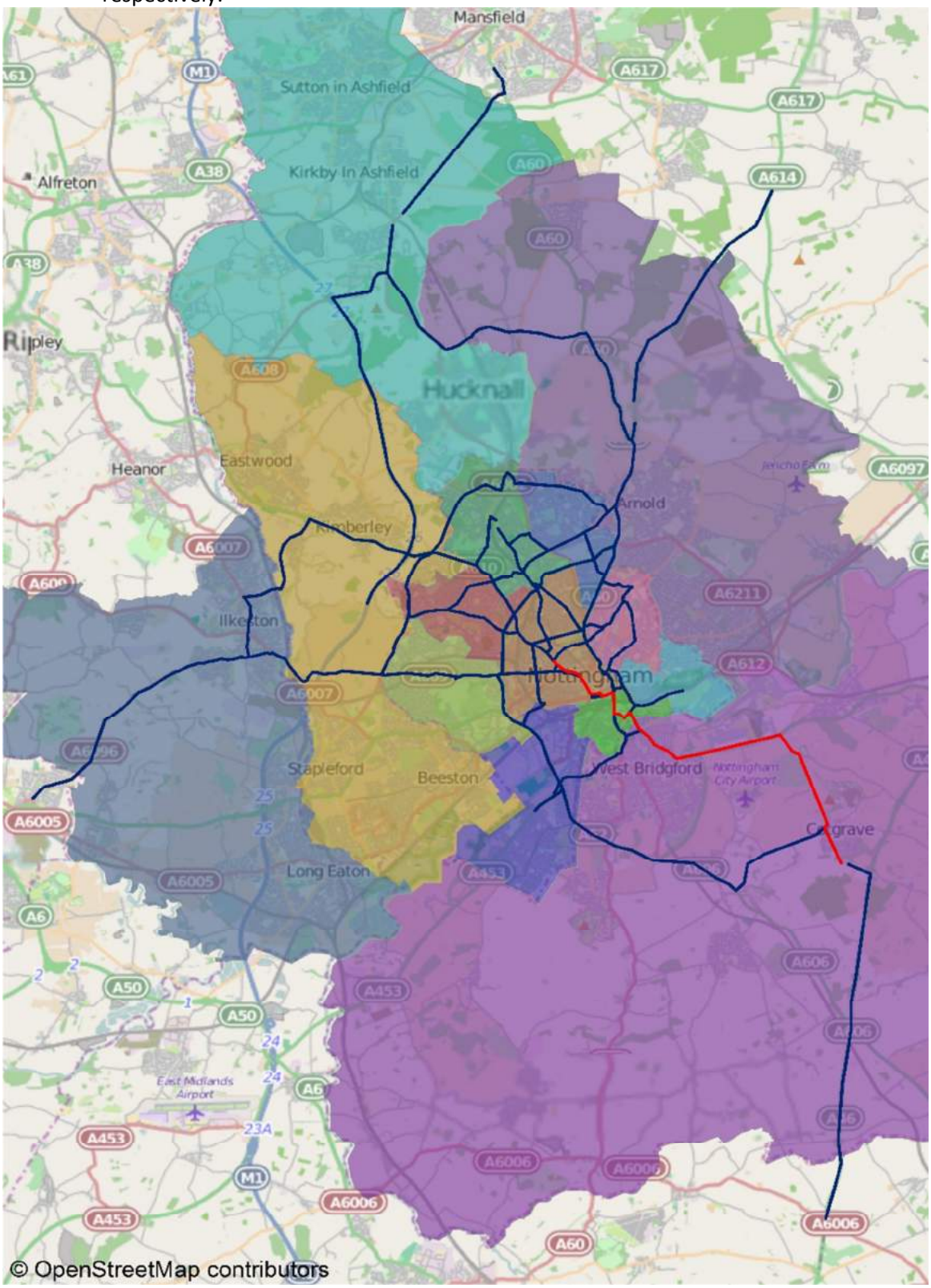

Figure 6. Highway Distances

Table 3. **Highway Distances (Km)**

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.6	6.7	3.2	5.1	3.8	5.3	4.8	3.4	3.3	13.8	18.7	8.3	14.1	8.6	51.0
2	6.7	2.3	4.6	7.4	8.4	12.0	11.2	6.8	8.4	13.9	25.7	15.3	17.4	15.8	51.0
3	3.2	4.6	1.3	2.6	3.6	7.0	7.6	6.3	6.7	10.4	22.1	11.7	16.9	10.2	51.0
4	5.1	7.4	2.6	1.3	4.9	8.6	9.2	8.1	8.4	11.9	23.8	13.4	18.7	11.9	51.0
5	3.8	8.4	3.6	4.9	1.8	4.4	6.9	7.3	6.7	13.7	22.1	11.7	17.9	7.7	51.0
6	5.3	12.0	7.0	8.6	4.4	1.5	3.0	7.9	6.4	17.3	18.3	7.9	16.4	4.4	51.0
7	4.8	11.2	7.6	9.2	6.9	3.0	1.5	6.8	5.0	18.0	16.5	6.1	16.1	7.6	51.0
8	3.4	6.8	6.3	8.1	7.3	7.9	6.8	1.7	4.2	16.7	20.2	9.8	10.9	11.6	51.0
9	3.3	8.4	6.7	8.4	6.7	6.4	5.0	4.2	1.6	17.1	17.3	6.9	12.1	10.2	51.0
10	13.8	13.9	10.4	11.9	13.7	17.3	18.0	16.7	17.1	4.9	36.2	25.8	27.9	20.7	51.0
11	18.7	25.7	22.1	23.8	22.1	18.3	16.5	20.2	17.3	36.2	2.3	14.5	25.2	13.6	51.0
12	8.3	15.3	11.7	13.4	11.7	7.9	6.1	9.8	6.9	25.8	14.5	3.0	14.8	13.5	51.0
13	14.1	17.4	16.9	18.7	17.9	16.4	16.1	10.9	12.1	27.9	25.2	14.8	1.7	22.2	51.0
14	8.6	15.8	10.2	11.9	7.7	4.4	7.6	11.6	10.2	20.7	13.6	13.5	22.2	2.2	51.0
15	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0	0.0

Table 4. **Bus Distances (Km)**

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.7	8.0	3.5	5.0	3.8	7.1	7.4	4.1	3.5	14.1	18.5	7.6	13.4	9.9	32.0
2	8.0	1.0	4.6	9.4	9.5	12.8	13.2	10.7	11.1	14.2	24.2	14.3	20.0	15.6	0.0
3	3.5	4.6	0.2	4.9	5.0	8.3	8.7	6.2	6.6	10.7	19.7	9.8	15.5	11.1	0.0
4	5.0	9.4	4.9	2.4	6.8	10.1	10.5	8.1	8.5	15.1	21.6	11.6	17.4	13.0	0.0
5	3.8	9.5	5.0	6.8	1.9	4.7	8.5	6.7	7.1	15.8	17.2	10.3	16.0	7.5	0.0
6	7.1	12.8	8.3	10.1	4.7	2.3	5.4	10.0	10.4	19.1	14.1	13.6	19.3	5.2	32.0
7	7.4	13.2	8.7	10.5	8.5	5.4	2.0	10.7	4.1	19.5	11.6	9.2	14.9	12.3	32.0
8	4.1	10.7	6.2	8.1	6.7	10.0	10.7	1.9	7.5	17.0	21.4	3.8	9.5	12.8	32.0
9	3.5	11.1	6.6	8.5	7.1	10.4	4.1	7.5	1.7	17.5	21.8	5.9	11.6	13.2	32.0
10	14.1	14.2	10.7	15.1	15.8	19.1	19.5	17.0	17.5	5.3	30.3	20.4	26.1	21.7	0.0
11	18.5	24.2	19.7	21.6	17.2	14.1	11.6	21.4	21.8	30.3	3.5	25.0	30.7	21.7	32.0
12	7.6	14.3	9.8	11.6	10.3	13.6	9.2	3.8	5.9	20.4	25.0	1.9	5.9	16.4	32.0
13	13.4	20.0	15.5	17.4	16.0	19.3	14.9	9.5	11.6	26.1	30.7	5.9	2.7	22.1	32.0
14	9.9	15.6	11.1	13.0	7.5	5.2	12.3	12.8	13.2	21.7	21.7	16.4	22.1	2.6	32.0
15	32.0	0.0	0.0	0.0	0.0	32.0	32.0	32.0	32.0	0.0	32.0	32.0	32.0	32.0	0.0

Table 5. **Rail Distances (Km)**

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	8.8	0.0	0.0	14.2	13.4	5.4	12.7	5.3	32.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	8.8	0.0	0.0	0.0	0.0	0.0	0.0	22.9	4.7	10.9	18.1	14.1	32.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	14.2	0.0	0.0	0.0	22.9	0.0	0.0	0.0	27.5	19.4	26.7	10.7	32.0
11	0.0	0.0	13.4	0.0	0.0	0.0	4.7	0.0	0.0	27.5	0.0	15.4	22.7	18.7	32.0
12	0.0	0.0	5.4	0.0	0.0	0.0	10.9	0.0	0.0	19.4	15.4	0.0	7.5	10.6	32.0
13	0.0	0.0	12.7	0.0	0.0	0.0	18.1	0.0	0.0	26.7	22.7	7.5	0.0	17.9	32.0
14	0.0	0.0	5.3	0.0	0.0	0.0	14.1	0.0	0.0	10.7	18.7	10.6	17.9	0.0	32.0
15	0.0	0.0	32.0	0.0	0.0	0.0	32.0	0.0	0.0	32.0	32.0	32.0	32.0	32.0	0.0

Table 6. **Tram Distances (Km)**

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.0	0.0	1.6	0.0	0.0	0.0	6.1	0.0	0.0	0.0	10.7	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1.6	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	0.0	12.3	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	6.1	0.0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	10.7	0.0	12.3	0.0	0.0	0.0	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

3.4 Public Transport Routes

3.4.1 Nottingham boasts an excellent public transport network, incorporating bus, rail and tram services, all of which are included in the model. Nottingham City Transport (NCT) operates local bus service routes, as illustrated in Figure 7, with Trent Barton operating bus services to the rural areas of Nottingham and neighbouring cities, as shown in Figure 8. Table 7 and Table 8 give details of the routes and the service frequency for NCT and Trent Barton respectively.

3.4.2 In addition to the bus services, the city has a north-south running tram line as shown in Figure 9, with service details provided in Table 9.

3.4.3 Finally, there are numerous rail services from Nottingham Central Station, located in zone 3, to local rail stations, as well as direct inter-city services to nearby cities such as Derby and Sheffield, as well as services to London. Figure 10 and Table 10 provide the relevant details regarding the rail services operating out of Nottingham.

3.4.4 Public Transport demand is allowed to take any route that is either direct, or involves one transfer. The route choice model then spreads the demand amongst all the possible routes for a given movement based on the generalised cost of the journey (made up of travel time, wait time, walking time, fare etc).

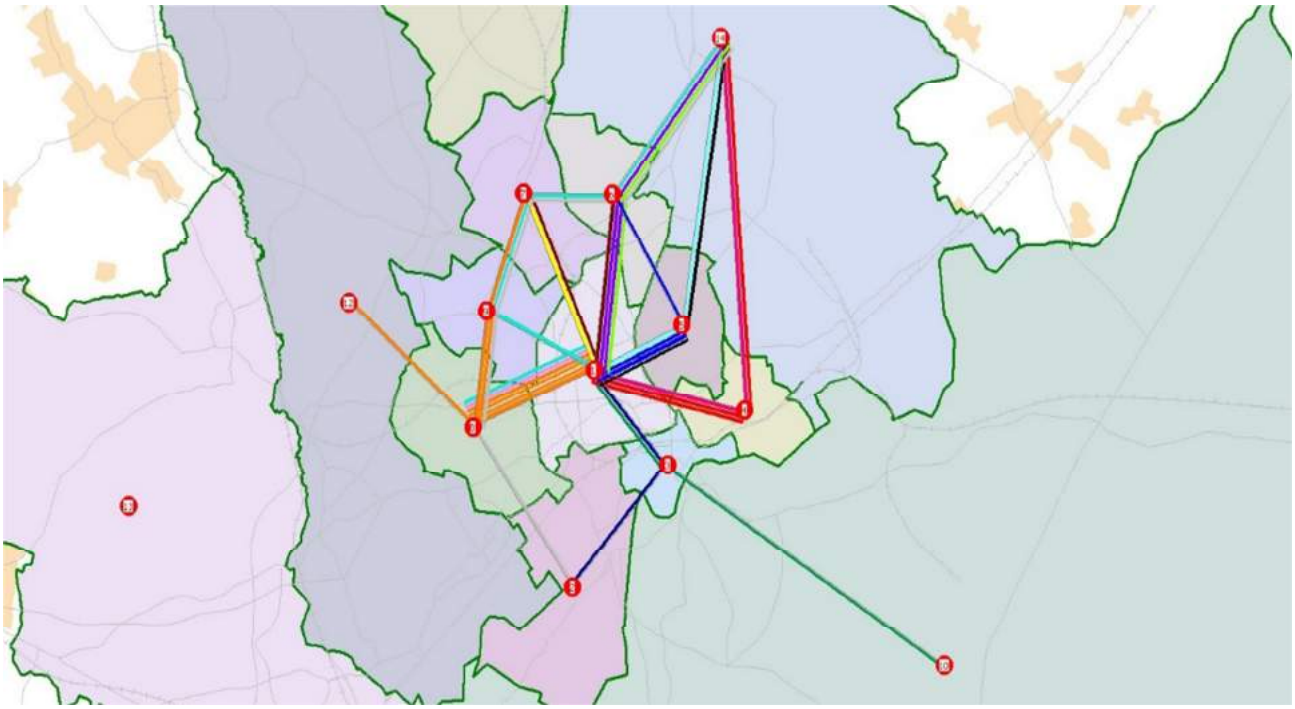

Figure 7. Nottingham City Transit Routes

Table 7. **Nottingham City Transit Routes**

ROUTE		FREQUENCY	ROUTE		FREQUENCY
	NAVY	301		LIME	174
	GREEN	290		SKY BLUE	122
	ORANGE	128		BLUE	218
	PINK	201		LILAC	167
	TURQUIOSE	196		RED	101
	YELLOW	168		GREY	28
	BROWN	100		PATHFINDER	28
	PURPLE	50			

Figure 8. Nottingham Trent Barton Routes

Table 8. **Nottingham Trent Barton Routes**

ROUTE		FREQUENCY	ROUTE		FREQUENCY
	Amberline	17		RedArrow	102
	Calverton	68		Ruddington	34
	Cotgrave	51		Rushcliffe	68
	IlkestonFlyer	51		Skylink	51
	i4	102		Threes	102
	Indigo	204		Two	85
	Keyworth	68		18	34
	Pronto	102		21	17
	RainbowOne	102		141	17
	RapidOne	17			

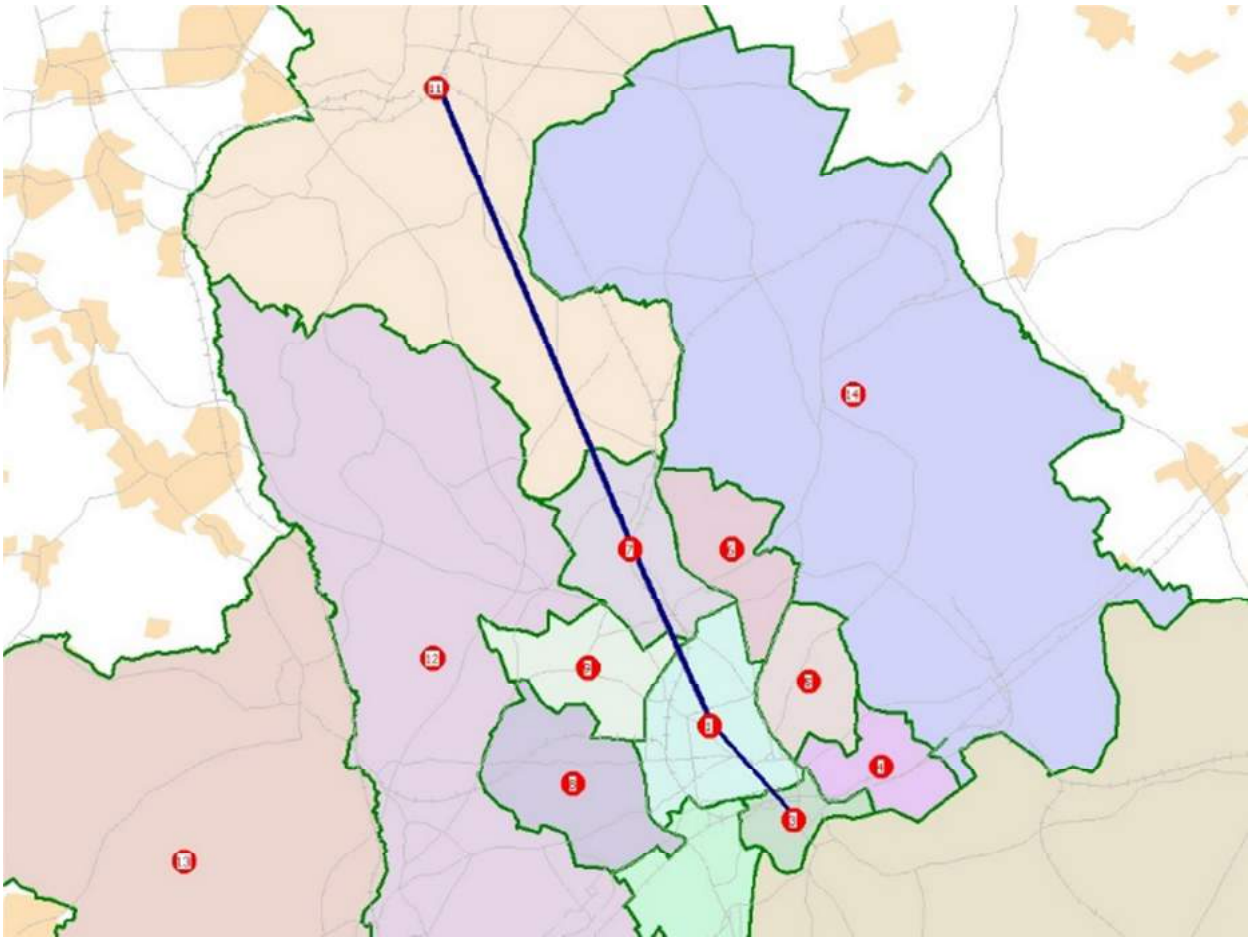

Figure 9. Nottingham Tram Services

Table 9. **Nottingham Tram Services**

ROUTE		FREQUENCY
	Tram North	204
	Tram South	204

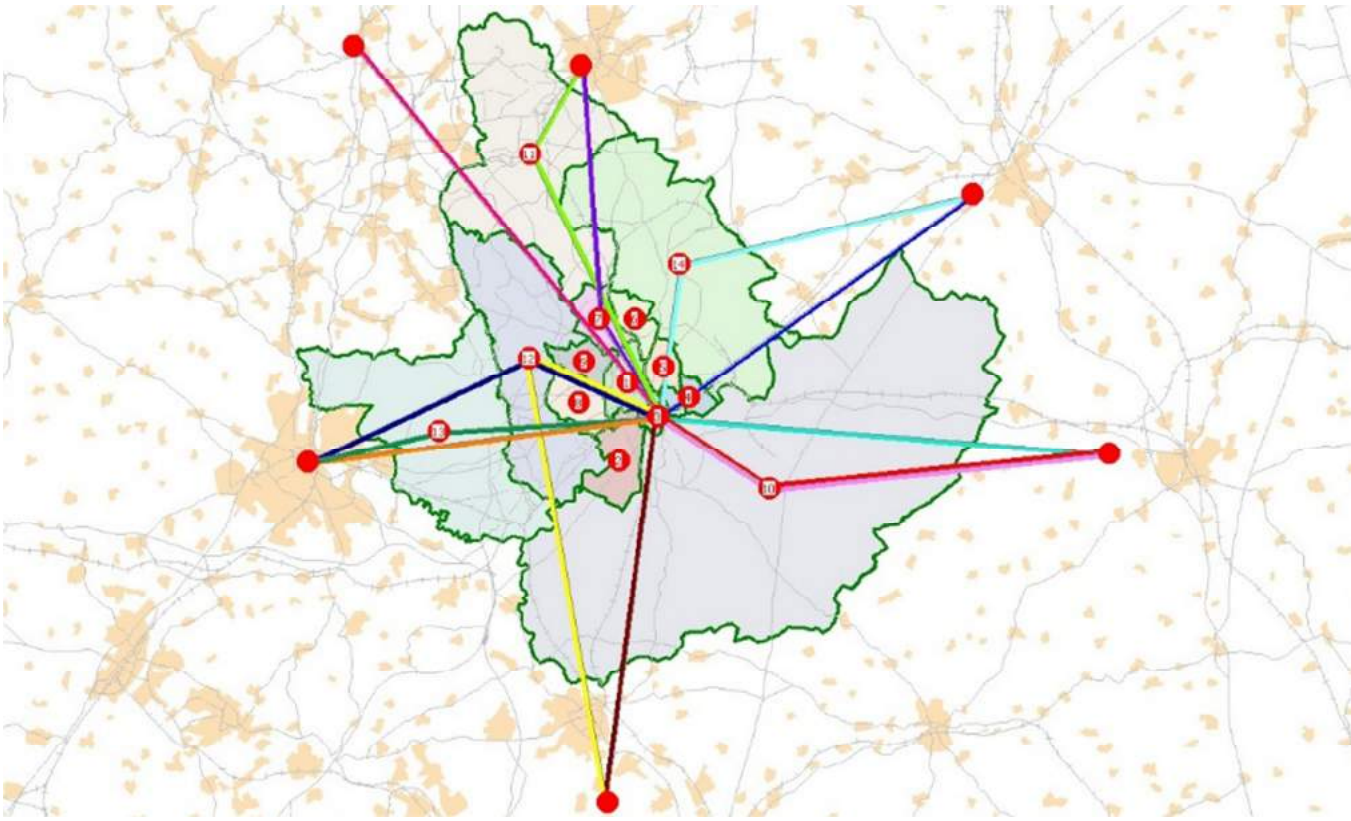

Figure 10. Nottingham Train Services

Table 10. **Nottingham Train Services**

ROUTE		FREQUENCY	ROUTE		FREQUENCY
	Grantham	17		Sheffield	17
	Skegness	2		Derby	37
	Grantham Direct	12		Derby Direct	15
	Newark	19		London	18
	Newark Direct	12		London Direct	15
	Mansfield	19			

3.5 Speeds

3.5.1 The speeds in the model are specified by Vehicle Type and Area Type. Table 11 shows the speeds used in the model, aggregated to groups of vehicle types with the same sets of speed. The groupings are;

- Cars: Petrol, Diesel, Petrol Full Hybrid, Diesel Full-Hybrid, Electric, LPG cars and Taxis;
- Goods Vehicles: Petrol and Diesel LGVs, Rigid and Artic HGVs;
- Buses: Diesel, Hybrid, Electric and Gas-powered buses;
- Trains: Diesel and Electric trains, and
- Trams.

Table 11. **Speeds by Vehicle and Area Type (Km/h)**

VEHICLE TYPE	CITY CENTRE	EDGE OF CITY CENTRE	SUBURBAN	RURAL/ OUTSIDE CITY	EXTERNAL
Cars	27	47	45	45	78
Goods Vehicles	33	51	63	63	81
Buses	17	18	19	19	30
Mopeds/Motorbikes	27	47	45	45	78
Train	64	64	62	62	82
Tram	18	20	24	24	16

3.5.2 The values for the speeds given in Table 11 have come from previous modelled journey times and distances, demand weighted to the Nottingham InSmart zone systems.

3.6 Vehicle Splits

3.6.1 The vehicle type splits were calculated using the following process;

- The split between Petrol, Diesel and LPG cars was taken from 2001-2013 vehicle fleet information provided by EUROSTAT. This gave the following splits;
  - Petrol: 68.4%
  - Diesel: 30.9%
  - LPG: 0.03%
- Figures for Hybrid and Electric cars were calculated from UK sales data from 2001 to 2013. These were taken from the International Council on Clean Transportation

website[1]. This gives a share of 0.53% for Hybrids, which is then broken down to the different Hybrid types using UK fleet data. The electric share is 0.03%.

- The split between cars and bikes, and between mopeds and motorbikes were taken from the European Commission Statistical Pocketbook 2012[2]. For Italy this gave the following;

  - 4% of vehicles are motorbikes or mopeds; and
  - 80% of these two-wheelers are motorbikes.

3.6.2 Combining these statistics gives the vehicle splits shown in Table 12 and Figure 11.

Table 12. **Vehicle Splits – Highway**

ID	VEHICLE TYPE	PERCENTAGE SPLIT
1	Petrol car inc Taxis	65.6%
2	Diesel car inc Taxis	29.7%
3	Petrol Full Hybrid Car	0.2%
4	Diesel Full Hybrid Car	0.1%
5	Petrol Plug-in Hybrid Car	0.2%
6	Electric Car	0.0%
15	Moped	0.8%
16	Motorcycle	3.3%
17	LPG Car	0.0%

[1] http://www.theicct.org/sites/default/files/publications/EU_pocketbook_2014.pdf
[2] http://ec.europa.eu/transport/facts-fundings/statistics/doc/2012/pocketbook2012.pdf

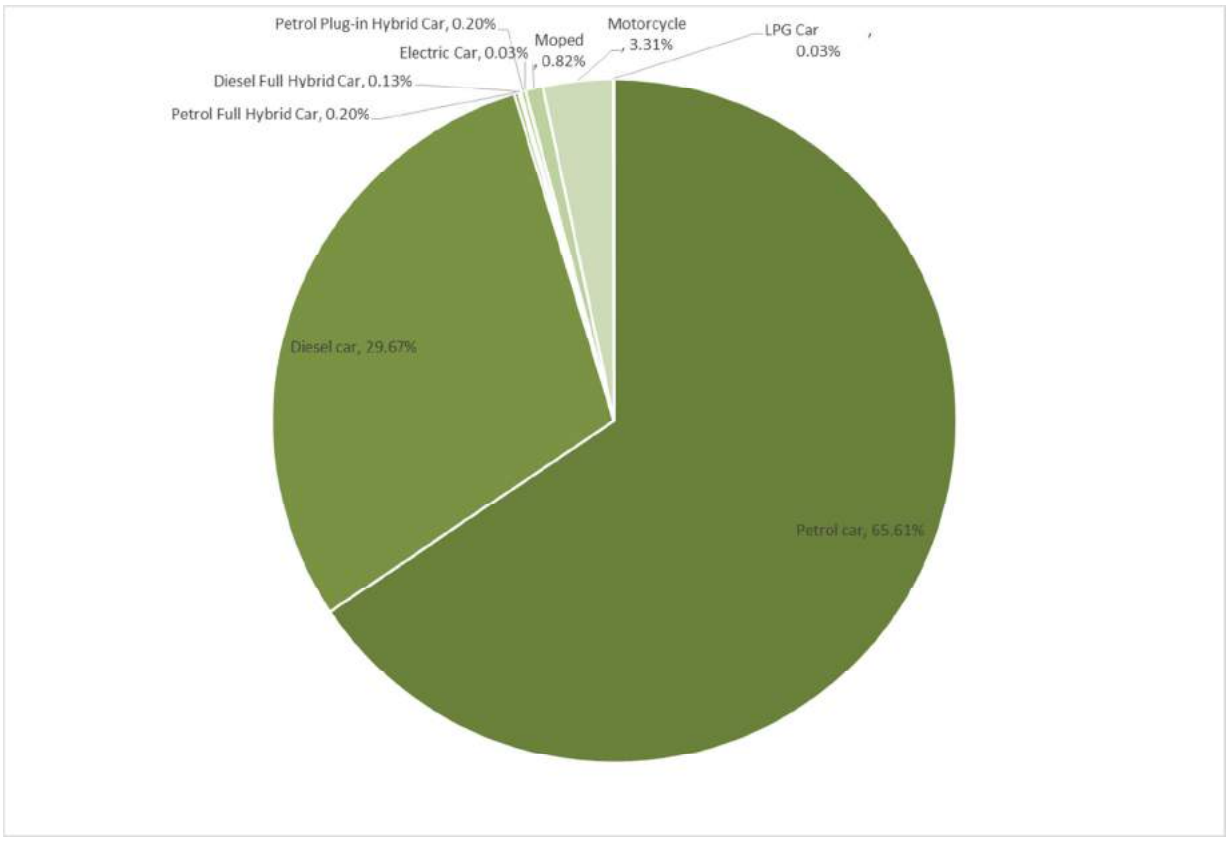

Figure 11. Highway Vehicle Splits

3.6.3 The split between different goods vehicles was taken from 2013 UK fleet split data. The values used are shown in Table 13 and Figure 12.

Table 13. **Goods Vehicle Splits**

ID	VEHICLE TYPE	PERCENTAGE SPLIT
7	Petrol LGV	2.00%
8	Diesel LGV	84.00%
9	Rigid HGV	11.00%
10	Artic HGV	3.00%

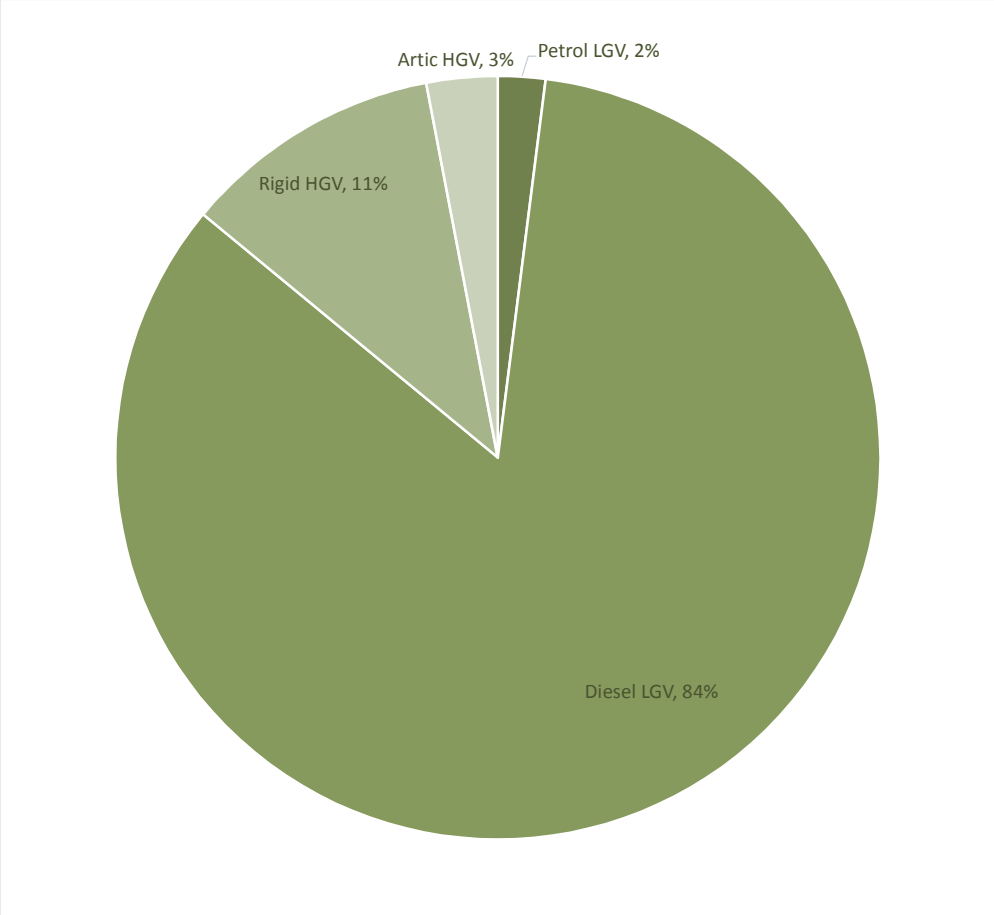

Figure 12. Goods Vehicle Splits

3.7 Internal & External Demand Splits

3.7.1 The external demand to and from the city is created by factoring the internal demand, which is taken from the Transport Model. For Nottingham the internal percentage is 76%, 87% and 73% of the total demand, for highway, PT and goods demand respectively.

3.8 Parking

3.8.1 For this model, 6 major car parks around the city centre of Nottingham have been identified as a means to provide a illustrative parking charge for the specific zones. All of the car parks are situated within zone 1, the exception being the Rail Station car park which is in zone 3. The parking charge varies depending on car park location and the duration of stay. Details of the car parks are shown in Table 14.

3.8.2 **Note**: There is no modelling of parking capacity within the model. The cost of parking is an additional cost included when travelling to a zone with car parking.

3.8.3 Parking charges represent an average charge incurred by all the trips terminating their journey in the zone containing the car park.

3.8.4 To calculate the total cost of parking for each purpose it has been assumed that work-based purposes park for an eight hour working day. All other purposes are assumed to park for two hours.

3.8.5 In addition, the charges have been reduced by one third to reflect the availability of work-place parking and free on-street parking. The resulting fares are shown in Table 15.

Table 14. **Car Parks In Nottingham**

CAR PARK NAME	CAPACITY	PRICE (£/2 HRS)	PRICE (£/8 HRS OR MORE)	ZONE
Lace Market	526	£3.80	£6.00	1
Broadmarsh	1200	£3.70	£6.00	1
Trinity Square	450	£4.10	£6.00	1
Nottingham Area	56	£2.00	£5.00	1
Nottingham Castle	58	£3.00	£5.00	1
Nottingham Rail Station	512	£4.00	£7.00	3

Table 15. **Parking Charges by Zone**

ZONE		WORK	OTHER
1	City Centre	£3.97	£2.47
3	Nottingham Rail Station	£4.67	£2.67

3.9 Public Transport Fares

3.9.1 The public transport fares are different for the three modes in Nottingham. Buses use a fare matrix, giving zone-zone fares. The zonal structure is fully illustrated in Table 16.

Table 16. **Bus Fares**

ORIGIN \ DESTINATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	£ 1.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.70	£ 3.20	£ 3.10	£ 3.10	£ 2.00	£ 2.00
2	£ 2.00	£ 1.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 4.70	£ 5.20	£ 5.10	£ 5.10	£ 2.00	£ 2.00
3	£ 2.00	£ 2.00	£ 1.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 4.70	£ 5.20	£ 5.10	£ 5.10	£ 2.00	£ 2.00
4	£ 2.00	£ 2.00	£ 2.00	£ 1.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 4.70	£ 5.20	£ 5.10	£ 5.10	£ 2.00	£ 2.00
5	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 1.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 4.70	£ 5.20	£ 5.10	£ 5.10	£ 2.00	£ 2.00
6	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 1.00	£ 2.00	£ 2.00	£ 2.00	£ 4.70	£ 5.20	£ 5.10	£ 5.10	£ 2.00	£ 2.00
7	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 1.00	£ 2.00	£ 2.00	£ 4.70	£ 5.20	£ 5.10	£ 5.10	£ 2.00	£ 2.00
8	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 1.00	£ 2.00	£ 4.70	£ 5.20	£ 3.10	£ 3.10	£ 2.00	£ 2.00
9	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 1.00	£ 4.70	£ 5.20	£ 5.10	£ 5.10	£ 2.00	£ 2.00
10	£ 2.70	£ 4.70	£ 4.70	£ 4.70	£ 4.70	£ 4.70	£ 4.70	£ 4.70	£ 4.70	£ 1.00	£ 5.90	£ 5.80	£ 5.80	£ 4.70	£ 4.70
11	£ 3.20	£ 5.20	£ 5.20	£ 5.20	£ 5.20	£ 5.20	£ 5.20	£ 5.20	£ 5.20	£ 5.90	£ 1.00	£ 6.30	£ 6.30	£ 5.20	£ 5.20
12	£ 3.10	£ 5.10	£ 5.10	£ 5.10	£ 5.10	£ 5.10	£ 5.10	£ 3.10	£ 5.10	£ 5.80	£ 6.30	£ 1.00	£ 1.90	£ 5.10	£ 5.10
13	£ 3.10	£ 5.10	£ 5.10	£ 5.10	£ 5.10	£ 5.10	£ 5.10	£ 3.10	£ 5.10	£ 5.10	£ 6.30	£ 1.90	£ 1.00	£ 5.10	£ 5.10
14	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 4.70	£ 5.20	£ 5.10	£ 5.10	£ 1.00	£ 2.00
15	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 2.00	£ 4.70	£ 5.20	£ 5.10	£ 5.10	£ 2.00	£ 1.00

3.9.2 The rail fares are similar to the bus fares, in the sense that they provide zone-zone fares. However, these fares are subject to a suitable rail station being present within a zone. As such, Table 17 shows the relevant fares for rail trips modelled.

Table 17. **Rail Fares**

ORIGIN \ DESTINATION	3	7	10	11	12	13	14	15
3	£ -	£ 2.30	£ 5.20	£ 2.40	£ 2.00	£ 4.40	£ 2.60	£ 13.20
7	£ 2.30	£ -	£ 4.90	£ 2.00	£ 3.50	£ 4.40	£ 4.20	£ 13.20
10	£ 5.20	£ 4.90	£ -	£ 4.90	£ 5.20	£ 6.80	£ 7.40	£ 22.70
11	£ 2.40	£ 2.00	£ 4.90	£ -	£ 3.50	£ 5.40	£ 4.20	£ 13.20
12	£ 2.00	£ 3.50	£ 5.20	£ 3.50	£ -	£ 2.10	£ 2.90	£ 13.20
13	£ 4.40	£ 4.40	£ 6.80	£ 5.40	£ 2.10	£ -	£ 5.80	£ 11.20
14	£ 2.60	£ 4.20	£ 7.40	£ 4.20	£ 2.90	£ 5.80	£ -	£ 13.20
15	£ 13.20	£ 13.20	£ 22.70	£ 13.20	£ 13.20	£ 11.20	£ 13.20	£ -

3.9.3 Tram fares are set at a flat fare rate of £2.20 per trip.

4. CALIBRATION

4.1 Introduction

4.1.1 The model has been calibrated based on the from-home demand matrices from the multi-modal model of Nottingham. This process is slightly circular as the trips ends have come from the same data, but this data has been matched to observed data when the model was originally developed. As such it provides a good enough source for checking mode shares and trip lengths.

4.2 Mode Share

4.2.1 The Multi-modal model has a car mode share of 85% across all zones and purposes. The model has a mode share of 87% - slightly more than observed, but acceptable.

4.2.2 Figure 13 shows the global modelled mode share. Figure 14 shows the mode share by purpose, with the work-based purposes having the highest car share.

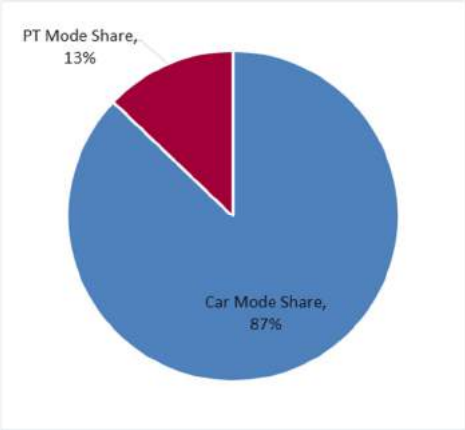

Figure 13. Global Mode Share

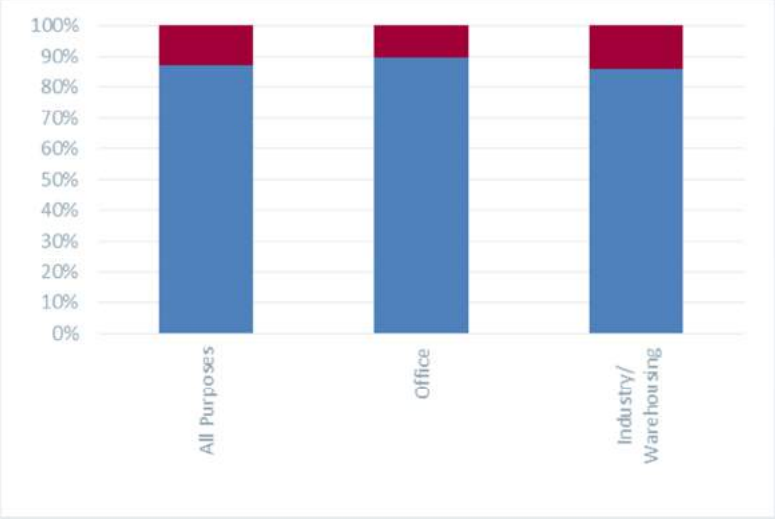

Figure 14. Mode Share by Purpose

4.3 Trip Length Distributions

4.3.1 The multi-model mode data has average trip lengths for car and public transport of 6.4km and 6.6km respectively. The modelled values are 7.1km and 6.1km.

4.3.2 The match of the highway to both average trip lengths and the overall trip length distribution is very good. Figure 15 shows the relative and cumulative frequencies of the observed and model distributions. Figure 16 shows the average trip lengths by purpose, which also shows a good match.

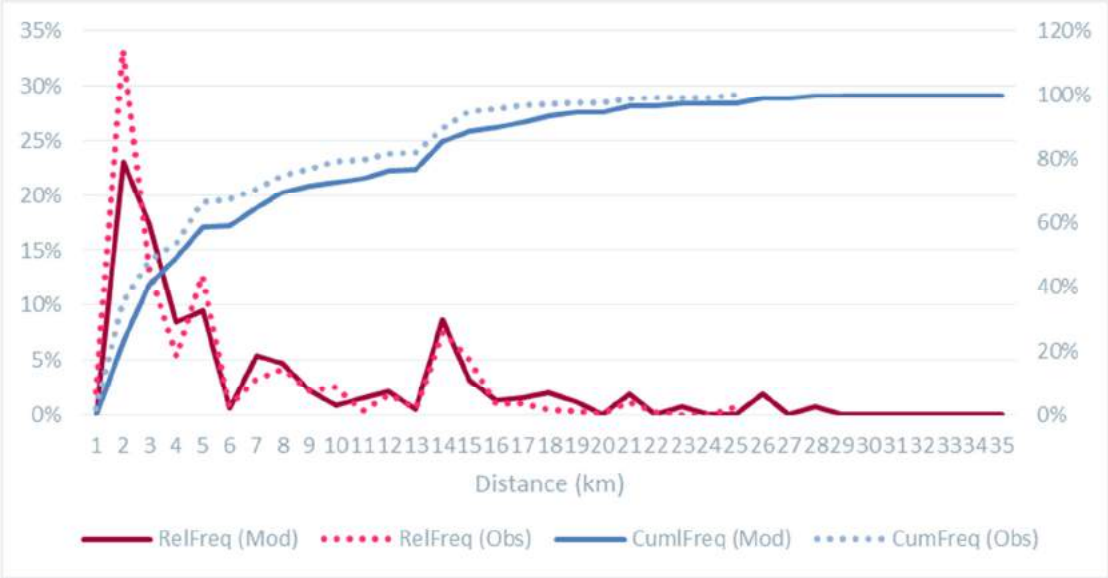

Figure 15. Highway Trip Length Distributions

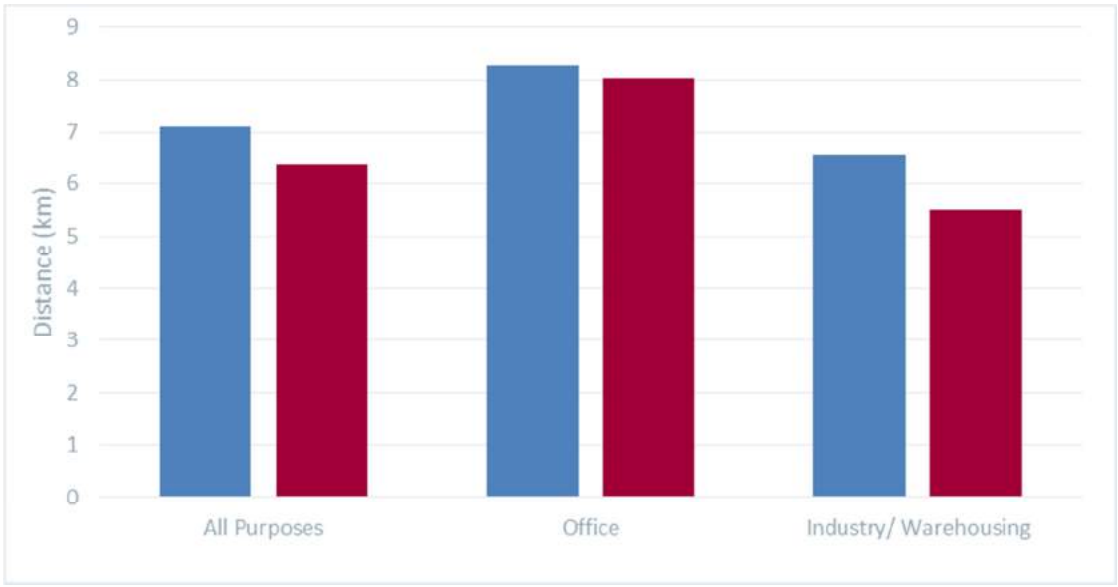

Figure 16. Highway Average Trip Lengths

4.3.3 The public transport distributions show a similarly good match. Figure 17 showing the distribution and Figure 18 showing the average trip lengths by purpose both illustrate this.

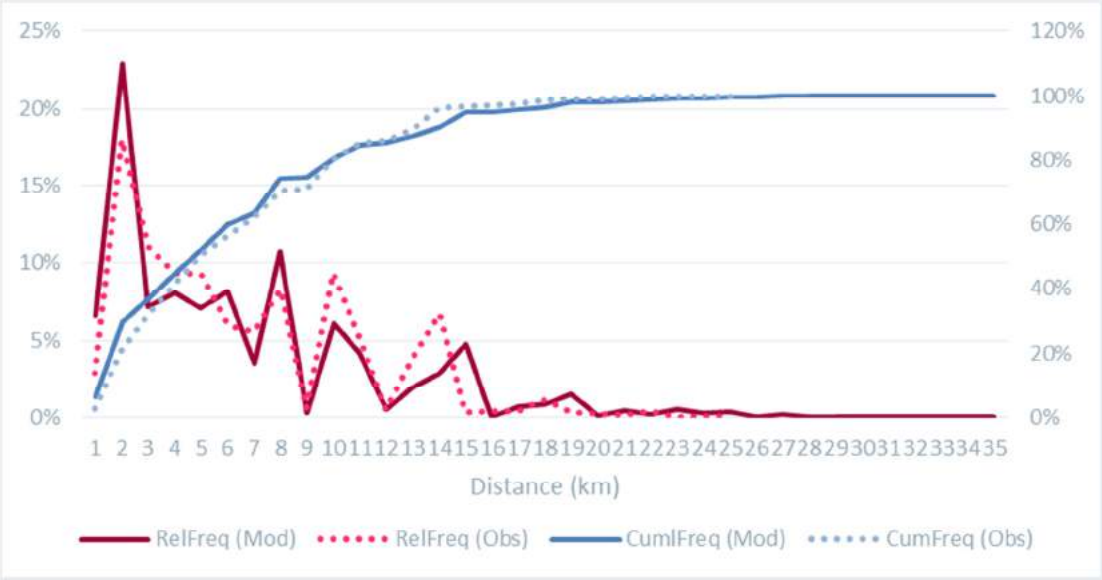

Figure 17. Public Transport Trip Length Distributions

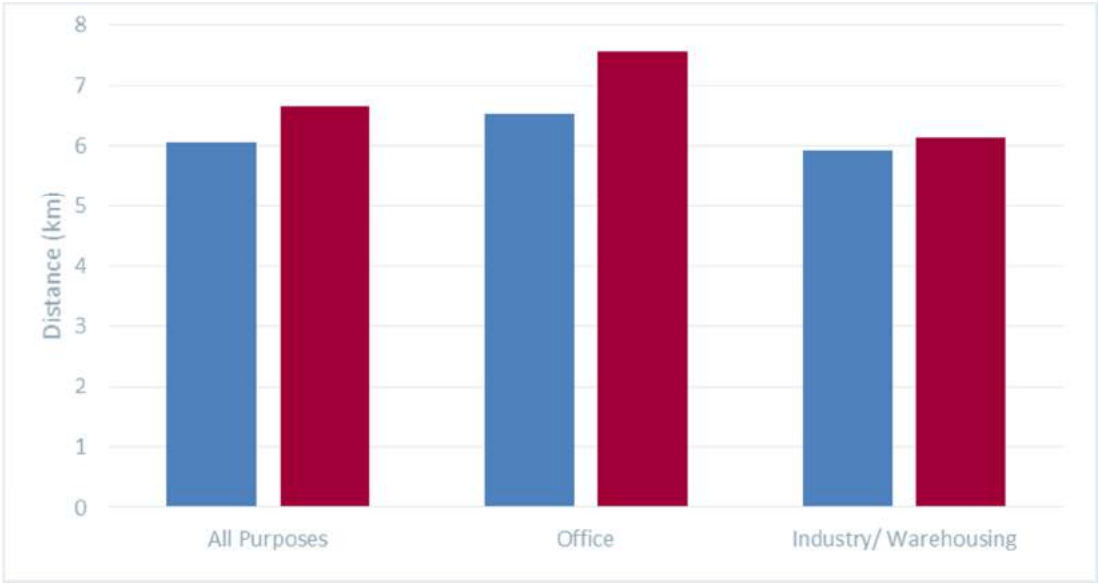

Figure 18. Public Transport Average Trip Lengths

5. OUTPUTS

5.1 Introduction

5.1.1 This section looks at the outputs from the base year model run. It is split into three sections;

- **Demand Outputs** – by Origin, Destination, Vehicle Type and a comparison to actual vehicle numbers;
- **Energy Consumption Outputs** – Total energy, per person, per trip and split by vehicle type; and
- **Other Emissions Outputs** – Carbon Dioxide, Hydro Carbons, PM10s and Nitrous Oxide emissions.

5.2 Demand Outputs

5.2.1 This sections looks at the various demand outputs, checking they are sensible and realistic. These include;

- Origin & Destination Plots;
- Demand by Purpose and Vehicle Type;
- Trip Rate checks;
- Comparison to actual vehicle figures; and
- Zone-Zone demand matrices.

5.2.2 Figure 19 shows the Origins and Destinations of the demand by zone. The origins and destinations both look sensible, with the city centre and the larger zones further out having the most demand. It can be seen that though the city centre is the largest attractor the zones surrounding it also attract trips – in fact more than they produce.

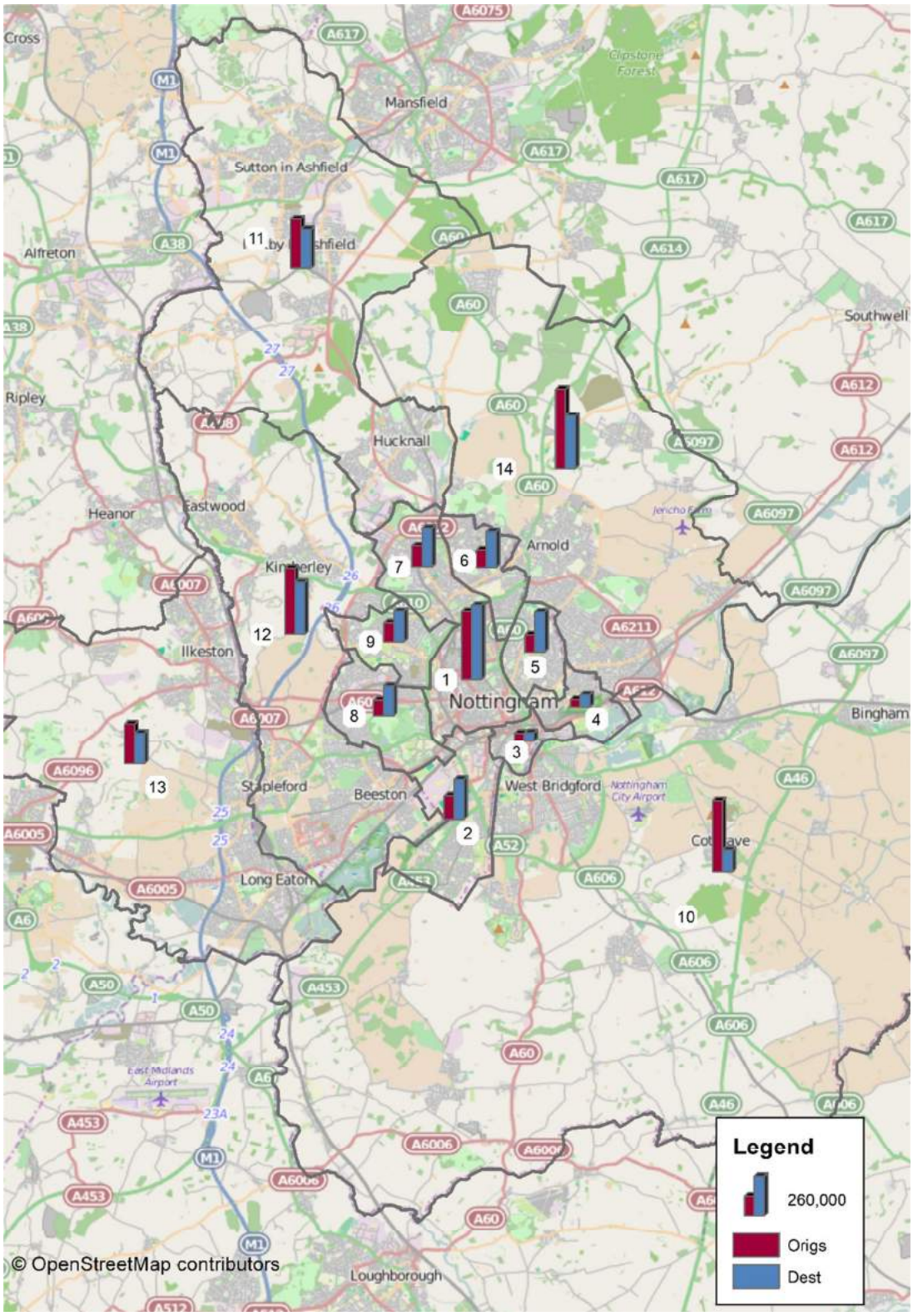

Figure 19. Origin & Destination Demand

5.2.3 Table 18 shows the demand split by purpose and mode (highway and PT). Highway based modes (including cars and motorbikes) make up most of the demand, particularly for work based purposes.

5.2.4 Table 18 also shows the average implied trip rate, per household, for each mode and purpose. Overall there are 3.54 two-way trips made each day per person.

Table 18. **Demand and Trip Rates By Purpose**

PURPOSE	HIGHWAY DEMAND	PT DEMAND	HY TRIP RATE	PT TRIP RATE	TOTAL TRIP RATE
Commute - Office	1,027,127	103,781	0.96	0.097	1.06
Other	2,326,078	328,376	2.18	0.307	2.48
Total	**3,353,205**	**432,157**	**3.14**	**0.404**	**3.54**
Mode Share	89%	11%			

5.2.5 Table 19 shows the demand split into Vehicle Types and total vehicle kilometres. For the Private vehicles and Goods vehicles this reflects the Vehicle Splits input to the model. Public transport demand makes up 6% of the total demand, but less than 1% of vehicles.

5.2.6 Figure 20 shows the vehicle type splits graphically.

Table 19. **Demand By Vehicle Type**

VEHICLE TYPE	PERSON DEMAND	VEHICLE DEMAND	% PERSON	% VEHICLES	VEHICLE KMS
Petrol car	2,199,971	1,533,820	54%	59%	27,222,899
Petrol Full Hybrid Car	6,572	4,582	0%	0%	81,327
Petrol Plug-in Hybrid Car	6,572	4,582	0%	0%	81,327
Diesel car	995,030	693,735	24%	27%	12,312,710
Diesel Full Hybrid Car	4,359	3,039	0%	0%	53,941
Electric Car	1,039	725	0%	0%	12,863
LPG Car	1,107	771	0%	0%	13,693
Moped	27,463	27,463	1%	1%	484,277
Motorcycle	111,092	111,092	3%	4%	1,958,985
Petrol LGV	5,112	3,628	0%	0%	73,763
Diesel LGV	214,688	152,373	5%	6%	3,098,030
Rigid HGV	28,114	28,114	1%	1%	571,607
Artic HGV	7,667	7,667	0%	0%	155,893
Buses	382,691	8,398	9%	0%	119,648
Tram	42,720	408	1%	0%	5,081
Diesel Train	52,874	495	1%	0%	19,254
Total	**4,087,072**	**2,580,893**	**100%**	**100%**	**46,265,298**

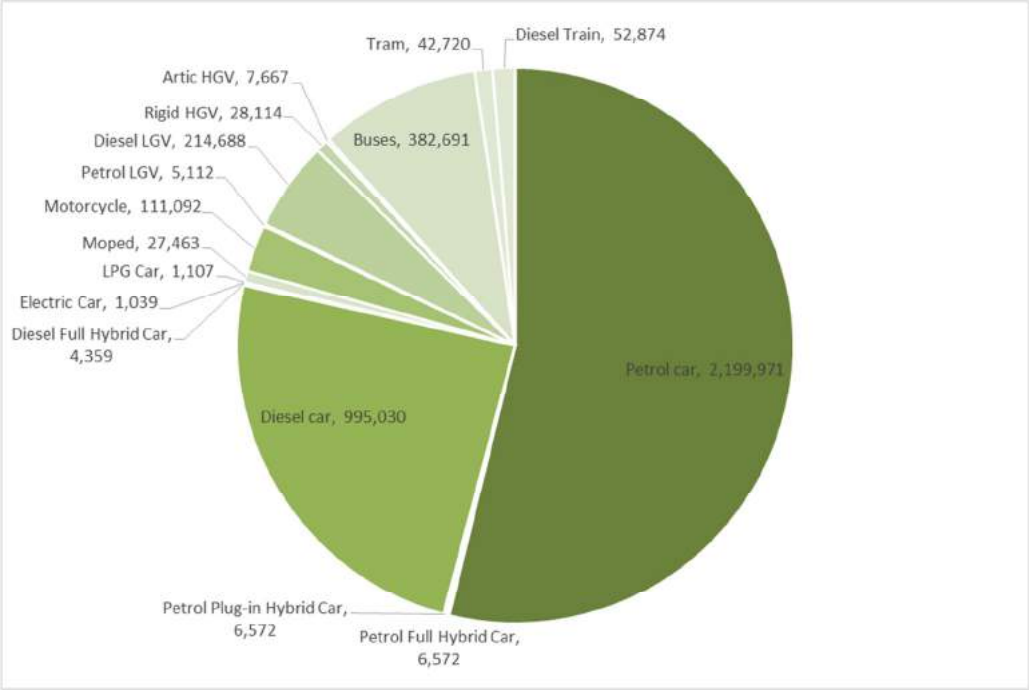

Figure 20. Demand By Vehicle Type

5.2.7 Table 20 to Table 22 show the zone-zone movements for Private Vehicles (Cars and motorbikes), Public Transport and Goods Vehicles.

5.2.8 The Private Vehicles demand is mainly focused on zone 1, as discussed previously. The PT demand also has a large proportion of demand going to zone 1 which reflects the relative accessibility of that zone via public transport and the impact of the parking charges.

Table 20. **Highway Demand**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
All Purposes	City Centre	Clifton	The Meadows	Colwick Park	St Ann's	Bestwood	Bulwell	Wollaton Park	Aspley	West Bridgford & South	Hucknall & North	Beeston & Kimberley	Ilkeston & Long Eaton	Arnold & East	External	Total	Origin Splits
1 City Centre	196564	12350	244	5114	28198	9834	13075	19385	19098	1710	1492	9954	2349	8009	51689	379066	11%
2 Clifton	1061	80548	154	3488	5526	1074	1729	8535	4140	1340	486	2410	1184	2098	17964	131739	4%
3 The Meadows	111	3591	22494	3915	3605	399	300	451	294	195	43	231	78	311	5687	41704	1%
4 Colwick Park	227	2897	39	20126	6044	688	548	633	426	379	88	420	147	618	5255	38534	1%
5 St Ann's	489	3004	53	3725	57154	9268	2234	1583	1573	528	207	1147	311	3344	13361	97982	3%
6 Bestwood	312	659	27	456	9711	37185	15140	1931	2695	224	339	2933	425	6188	12351	90574	3%
7 Bulwell	536	1351	38	494	3153	19011	48041	3756	6743	309	675	6990	657	4215	15152	111119	3%
8 Wollaton Park	659	6873	42	581	2266	2624	4033	39432	8419	330	410	2981	1551	1820	11372	83394	2%
9 Aspley	603	3982	37	481	2821	4588	8850	10033	45427	300	559	5499	1176	2352	13691	100400	3%
10 West Bridgford & South	29946	48608	4159	15760	34071	14576	16058	16469	12194	100301	10930	28186	15542	36251	60480	443531	13%
11 Hucknall & North	5457	5380	414	1181	4178	6106	9147	5462	6070	2448	163668	27215	5424	28988	42810	313947	9%
12 Beeston & Kimberley	9207	13340	607	2922	11799	24486	42668	18470	26764	3767	15442	142633	12403	22842	54843	402194	12%
13 Ilkeston & Long Eaton	5110	9858	410	1461	4608	5725	6811	14418	9199	3104	4461	18222	119315	7674	33217	243594	7%
14 Arnold & East	10961	14643	917	5207	36987	53539	33223	14787	15742	6192	20367	28253	6688	161041	64506	473053	14%
15 External	41248	32696	4680	10249	33176	29858	31871	24527	25071	19125	34604	43747	26407	45117	0	402375	12%
Total	302490	239778	34317	75158	243298	218961	233729	179871	183856	140253	253772	320821	193659	330867	402375	3353205	
Destination Splits	9%	7%	1%	2%	7%	7%	7%	5%	5%	4%	8%	10%	6%	10%	12%		

Table 21. **Public Transport Demand**

All Purposes	1 City Centre	2 Clifton	3 The Meadows	4 Colwick Park	5 St Ann's	6 Bestwood	7 Bulwell	8 Wollaton Park	9 Aspley	10 West Bridgford & South	11 Hucknall & North	12 Beeston & Kimberley	13 Ilkeston & Long Eaton	14 Arnold & East	15 External	Total	Origin Splits
1 City Centre	49630	1862	3641	1009	3724	1234	1624	2159	2410	66	479	595	198	511	5165	74306	17%
2 Clifton	7719	10770	2112	73	231	234	241	303	257	34	143	316	91	179	1696	24400	6%
3 The Meadows	4428	602	4717	23	78	31	197	50	51	5	60	175	34	67	786	11304	3%
4 Colwick Park	7422	120	179	2551	156	70	109	109	103	11	56	62	25	188	834	11996	3%
5 St Ann's	8117	110	175	45	6742	651	103	102	98	9	50	54	21	261	1236	17773	4%
6 Bestwood	9051	402	256	71	2244	8020	1820	357	490	20	175	103	42	951	1793	25794	6%
7 Bulwell	11474	408	1323	113	367	1749	7386	640	1747	28	1142	236	71	375	2022	29081	7%
8 Wollaton Park	12449	382	274	84	274	268	505	5467	717	18	100	797	235	171	1624	23367	5%
9 Aspley	12737	305	276	73	242	345	1288	648	6017	15	114	223	34	175	1681	24175	6%
10 West Bridgford & South	12385	1777	1217	404	1135	702	965	869	755	2963	1341	1985	848	1573	2160	31079	7%
11 Hucknall & North	7345	667	986	165	492	462	2113	367	429	120	3082	662	244	441	1313	18891	4%
12 Beeston & Kimberley	11699	1655	2853	232	686	378	805	2499	976	218	819	8710	2393	1008	2610	37540	9%
13 Ilkeston & Long Eaton	6127	728	1031	132	387	216	368	1243	254	119	412	3542	5346	511	1525	21942	5%
14 Arnold & East	18150	1857	2466	1040	4287	4063	2066	1349	1434	330	1017	1843	694	8179	3644	52420	12%
15 External	13353	1617	1607	449	1572	1376	1464	1207	1176	296	672	1442	768	1090	0	28089	6%
Total	192086	23265	23115	6463	22617	19798	21054	17370	16913	4253	9662	20746	11045	15680	28089	432157	
Destination Splits	44%	5%	5%	1%	5%	5%	5%	4%	4%	1%	2%	5%	3%	4%	6%		

Table 22. **Goods Vehicle Demand**

All Purposes	1 City Centre	2 Clifton	3 The Meadows	4 Colwick Park	5 St Ann's	6 Bestwood	7 Bulwell	8 Wollaton Park	9 Aspley	10 West Bridgford & South	11 Hucknall & North	12 Beeston & Kimberley	13 Ilkeston & Long Eaton	14 Arnold & East	15 External	Total	Origin Splits
1 City Centre	8288	1845	2479	819	1793	603	1197	2030	1272	1078	311	2726	888	2473	5141	32943	13%
2 Clifton	2277	3225	1787	496	611	148	324	925	421	721	124	934	447	887	2464	15791	6%
3 The Meadows	1852	1071	2785	700	680	128	198	320	174	381	52	425	156	512	1744	11177	4%
4 Colwick Park	823	400	951	658	361	71	113	162	89	226	32	245	92	305	837	5365	2%
5 St Ann's	1652	428	830	318	1166	264	238	266	178	266	52	428	139	780	1295	8300	3%
6 Bestwood	567	108	171	66	279	298	334	159	125	93	39	406	97	648	627	4016	2%
7 Bulwell	1219	260	290	116	274	351	951	372	323	185	96	1063	213	821	1208	7743	3%
8 Wollaton Park	2069	740	455	163	302	169	365	1513	461	254	94	875	426	657	1580	10121	4%
9 Aspley	1209	305	226	81	184	121	294	429	573	126	60	649	202	413	901	5774	2%
10 West Bridgford & South	4080	2210	2025	864	1200	426	775	1073	601	4327	408	2320	1157	2744	4477	28687	11%
11 Hucknall & North	952	326	261	111	201	138	298	307	212	298	793	1213	358	1266	1245	7980	3%
12 Beeston & Kimberley	4633	1371	1155	468	903	733	1704	1528	1181	1021	711	7619	1518	2896	5075	32517	13%
13 Ilkeston & Long Eaton	2110	891	596	246	417	262	521	1016	540	680	281	2048	3444	1214	2638	16903	7%
14 Arnold & East	4527	1415	1454	612	1595	1121	1450	1276	861	1342	798	3118	984	7940	5269	33762	13%
15 External	6705	2699	2860	1057	1843	894	1620	2103	1297	2034	712	4451	1871	4356	0	34503	13%
Total	42962	17296	18325	6776	11811	5725	10382	13478	8309	13031	4562	28519	11991	27912	34503	255581	
Destination Splits	17%	7%	7%	3%	5%	2%	4%	5%	3%	5%	2%	11%	5%	11%	13%		

5.2.9 Table 23 shows the public transport boardings by bus and train. On average there is an average occupancy of 51.4 people per vehicle. This is higher than in the other cities, but the number of services and connectivity is also much higher.

Table 23. **PT Demand by Vehicle Type**

ROUTE NO	BOARDINGS	DAILY SERVICES	AVERAGE OCCUPANCY
Buses	382,691	8,398	45.6
Tram	42,720	408	104.7
Train	52,874	495	106.8
Total	**478,285**	**9,301**	**51.4**
Demand	432,157		
Average Boardings Per Journey	1.11		

5.3 Energy Outputs

5.3.1 This section covers the Energy Consumption/Usage within Nottingham. This includes;

- Total Energy per person, trip and vehicle type;
- Energy by Origin zone; and
- Zone-zone Energy flows.

5.3.2 Table 24 presents a summary of the total energy used by transport within Nottingham. The total value across all modes, vehicle types, purposes and zones is **152,225,519 MJ**, which is around 142.4MJ per person per day.

5.3.3 This is considerably higher than the other cities, which could be down to a larger proportion of demand going to/from the external zone and a longer external distance (over 50% of the energy consumption is to/from the External zone). In addition, the internal trip length is longer.

Table 24. **Energy Usage Summary**

NO	TOTAL	CARS	BIKES	GOODS	BUSES	TRAMS	TRAINS
Total Energy (MJ)	152,225,519	123,142,621	4,779,278	22,311,805	1,640,271	-	351,543
Population	1,068,955						
Energy Per Person (MJ)	142.4	115.2	4.5	20.9	1.5	-	0.3
Demand (Persons)	4,087,072	3,214,651	138,554	255,581	382,691	42,720	52,874
Energy Per Trip (MJ)	37.2	38.3	34.5	87.3	4.3	-	6.6
Trips Per Person	3.8	3.0	0.1	0.2	0.4	0.0	0.05
Actual Vehicles	810,569	714,481	44,169	42,618	8,398	408	495
Energy Per Vehicle (MJ)	187.8	172.4	108.2	523.5	195.3	-	710.2
Vehicles Per Person	0.76	0.67	0.04	0.04	0.01	0.00	0.000

Note 1: Energy per Person for Goods demand isn't really meaningful as the demand is not based on residential locations. An increase in population would not necessarily lead to an increase in goods demand in the same way it would with car demand.

5.3.4 Table 25 shows the Energy figures split into Vehicles Types. Unsurprisingly Goods demand use the most energy compared to the number of vehicles – consuming 15% of the total energy from less than 1% of the vehicles.

5.3.5 Figure 21 shows the Energy Usage split by Vehicle Type.

Table 25. **Energy Consumption (MJ) by Vehicle Type**

VEHICLE TYPE	TOTAL ENERGY	% ENERGY	VEHICLES	ENERGY PER VEHICLE
Petrol car	87,236,499	57%	488,960	178
Petrol Full Hybrid Car	142,356	0%	1,461	97
Petrol Plug-in Hybrid Car	136,980	0%	1,461	94
Diesel car	35,487,475	23%	221,153	160
Diesel Full Hybrid Car	84,881	0%	969	88
Electric Car	5,514	0%	231	24
LPG Car	48,917	0%	246	199
Moped	538,770	0%	8,755	62
Motorcycle	4,240,508	3%	35,414	120
Petrol LGV	302,559	0%	806	375
Diesel LGV	12,392,217	8%	33,861	366
Rigid HGV	6,674,848	4%	6,248	1,068
Artic HGV	2,942,181	2%	1,704	1,727
Buses	1,640,271	1%	8,398	195
Tram	-	0%	495	710
Diesel Train	351,543	0%	495	710
Total	**152,225,519**	**100%**	**810,569**	**188**
Cars	123,142,621	81%	714,480	172
Bikes	4,779,278	3%	44,169	108
Goods	22,311,805	15%	42,618	524
Buses	1,640,271	1%	8,398	195
Trams	-	0%	408	-
Trains	351,543	0%	495	710

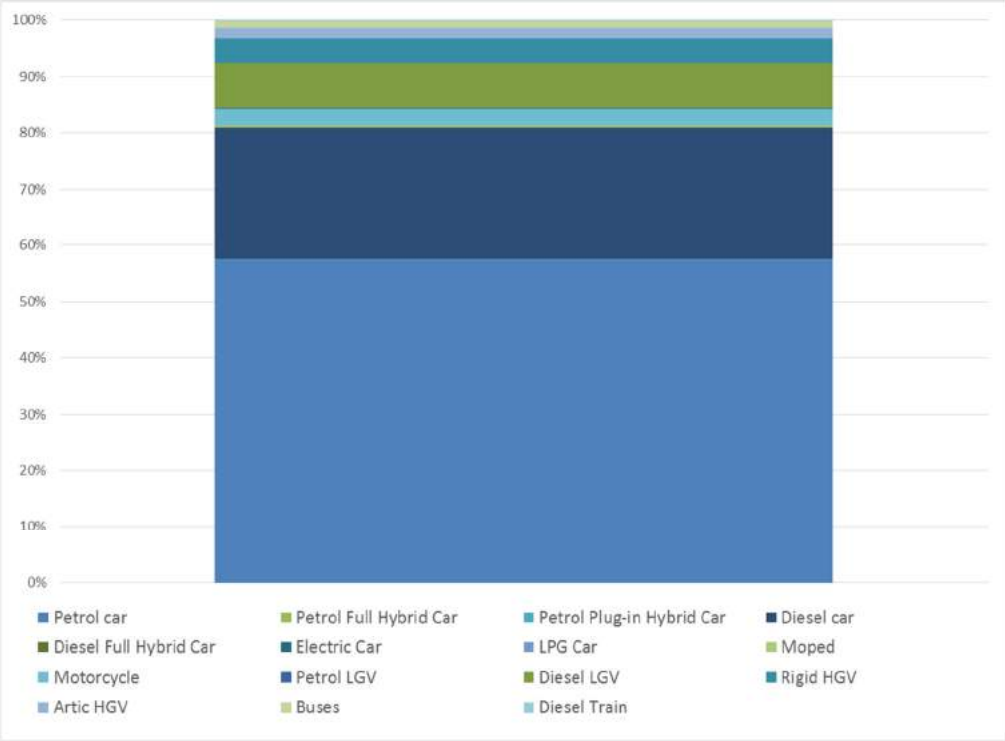

Figure 21. Energy Usage By Vehicle Type

5.3.6 Table 26 shows the Energy Usage split into zones, based on the residential origin of the trip. Figure 22 shows the total energy per zone and Figure 23 shows the energy per person. There are a number effects present here;

- Zones further out consume more energy due to the distance they have to travel, primarily to central zones.
- However, the ring of zones surrounding the city centre shows less energy usage do to a combination of lower population and shorter distances to the main attractors in the city centre and the zones themselves.
- The city centre zone has a higher population than the zones surrounding it (comparable to the furthest ring of zones) leading to a higher energy usage. However, on a MJ per person basis this is higher, potentially pointing to a large number of trips being made from the central zone outwards.

Table 26. **Energy Per Zone – Private Vehicles**

NO	ZONE NAME	AREA TYPE	POPULATION	DEMAND	ENERGY (MJ)	ENERGY/ PERSON	ENERGY/ TRIP
1	City Centre	1	88,948	261,194	7,559,171	85.0	28.9
2	Clifton	2	39,780	93,448	2,852,132	71.7	30.5
3	The Meadows	2	16,096	30,639	700,815	43.5	22.9
4	Colwick Park	2	28,930	27,115	719,743	24.9	26.5
5	St Ann's	2	41,721	70,260	1,815,026	43.5	25.8
6	Bestwood	2	45,158	65,396	1,716,763	38.0	26.3
7	Bulwell	2	42,787	78,893	2,192,923	51.3	27.8
8	Wollaton Park	2	42,671	59,894	1,716,950	40.2	28.7
9	Aspley	2	40,274	72,285	1,966,148	48.8	27.2
10	West Bridgford & South	3	128,757	321,816	26,292,832	204.2	81.7
11	Hucknall & North	3	133,342	219,463	11,385,852	85.4	51.9
12	Beeston & Kimberley	3	132,658	284,178	13,545,265	102.1	47.7
13	Ilkeston & Long Eaton	3	129,362	177,484	8,614,555	66.6	48.5
14	Arnold & East	3	132,553	332,173	16,583,912	125.1	49.9
15	External	5	-	285,571	30,259,811	-	106.0
	Total (inc External)	**-**	**-**	**4,759,618**	**255,843,799**	**-**	**53.8**
	Total (exl External)	**-**	**1,043,037**	**2,379,809**	**127,921,899**	**122.6**	**53.8**

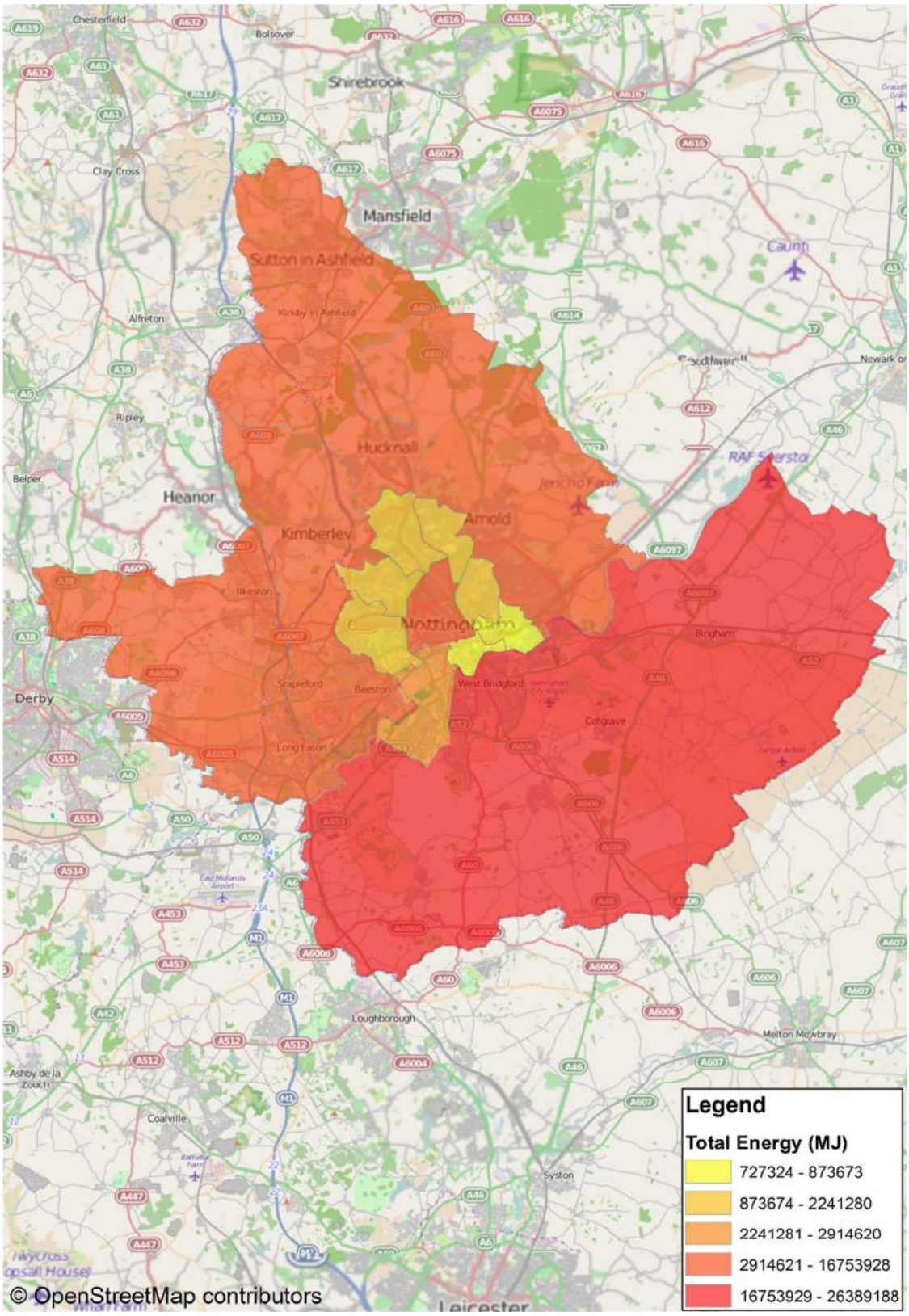

Figure 22. Total Energy (MJ) Per Origin Zone

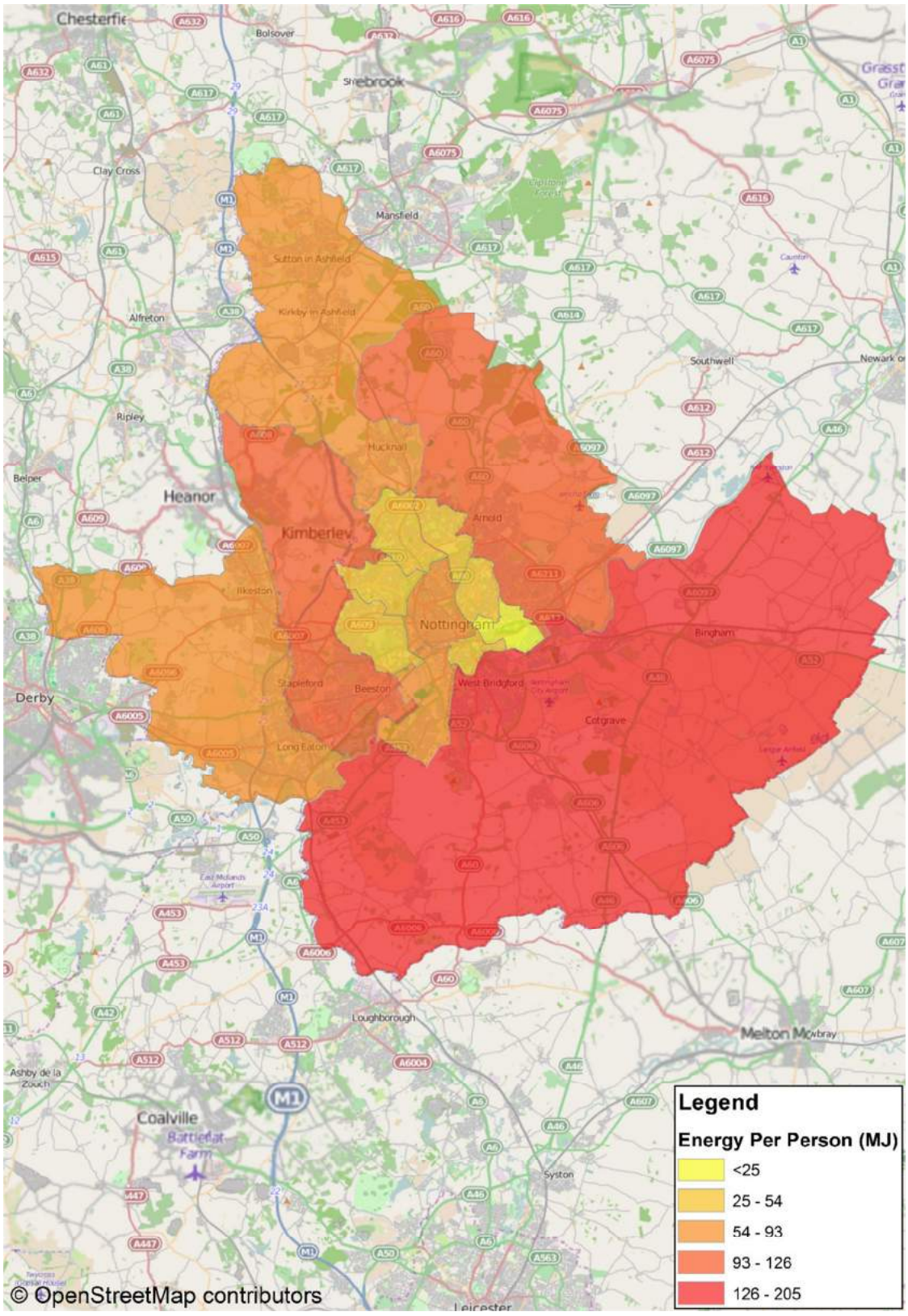

Figure 23. Energy (MJ) per Population

5.3.7 Table 27 to Table 29 show the zone-zone energy usage flows. The highway and goods matrices are similar to the demand matrices.

5.3.8 However, the Public Transport energy is calculated on the basis of the actual vehicles serving the routes, rather than the demand. They are then allocated based on the start and end zone of each service. Hence, the majority of the PT energy is to/from zone 1 which is where most routes start or end.

Table 27. **Zonal Energy Usage – Private Vehicles**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
All Cars	City Centre	Clifton	The Meadows	Colwick Park	St Ann's	Bestwood	Bulwell	Wollaton Park	Aspley	West Bridgford & South	Hucknall & North	Beeston & Kimberley	Ilkeston & Long Eaton	Arnold & East	External	Total	Origin Splits
1 City Centre	1,738,724	197,953	2,563	64,582	296,420	129,517	165,588	216,005	194,506	65,357	53,903	211,848	70,441	182,777	3,679,514	7,269,696	6%
2 Clifton	16,830	751,725	1,806	51,929	92,500	25,536	37,993	129,497	68,727	51,404	22,783	75,209	41,332	68,628	1,309,890	2,745,788	2%
3 The Meadows	1,063	38,690	109,494	25,839	30,250	5,782	4,785	6,557	4,217	6,304	1,873	6,206	2,756	7,784	423,750	675,349	1%
4 Colwick Park	2,909	44,606	291	110,791	62,395	11,714	10,077	11,269	7,418	13,236	4,054	12,546	5,666	17,039	378,843	692,854	1%
5 St Ann's	5,213	53,087	505	38,931	357,174	93,055	32,884	26,048	22,724	20,266	9,014	30,975	11,612	69,058	977,562	1,748,107	1%
6 Bestwood	4,221	16,568	429	7,819	97,451	234,267	129,793	31,670	35,404	10,274	12,446	59,735	14,370	99,704	899,501	1,653,651	1%
7 Bulwell	7,110	31,898	667	9,289	47,172	169,382	342,371	57,381	77,657	14,537	22,802	125,131	22,042	88,641	1,095,075	2,111,155	2%
8 Wollaton Park	7,228	104,219	645	9,944	35,453	41,131	57,722	296,658	87,850	14,706	15,869	68,249	38,736	48,433	826,476	1,653,319	1%
9 Aspley	6,201	69,395	580	8,440	40,570	60,286	99,006	108,184	286,730	13,672	19,403	102,202	31,674	57,293	990,009	1,893,645	2%
10 West Bridgford & South	1,373,787	2,282,983	172,425	650,992	1,500,303	746,394	829,066	860,451	617,181	4,545,911	881,217	1,854,312	1,093,860	2,175,256	5,764,488	25,348,626	21%
11 Hucknall & North	215,685	274,314	19,433	55,276	183,754	233,182	321,849	230,724	220,028	193,088	3,315,883	1,000,199	289,391	1,053,809	3,352,740	10,959,354	9%
12 Beeston & Kimberley	227,417	469,081	18,732	92,848	340,761	564,466	874,030	491,270	572,436	237,076	564,807	2,938,196	468,009	816,716	4,367,927	13,043,772	11%
13 Ilkeston & Long Eaton	168,008	378,621	15,838	57,435	175,167	201,144	234,611	407,178	263,408	207,179	234,523	677,268	2,234,441	374,365	2,674,578	8,303,763	7%
14 Arnold & East	298,491	552,934	27,650	159,890	893,603	1,080,279	809,869	462,939	435,741	358,647	758,276	1,040,298	338,160	3,582,056	5,163,719	15,962,551	13%
15 External	2,854,516	2,381,805	345,794	719,474	2,340,489	2,098,448	2,213,597	1,769,161	1,732,268	1,601,050	2,482,661	3,253,921	1,970,388	3,317,417	-	29,080,989	24%
Total	6,927,401	7,647,879	716,851	2,063,480	6,493,460	5,694,584	6,163,240	5,104,992	4,626,295	7,352,706	8,399,513	11,456,295	6,632,878	11,958,975	31,904,072	123,142,621	
Destination Splits	6%	6%	1%	2%	5%	5%	5%	4%	4%	6%	7%	9%	5%	10%	26%		

Table 28. **Zonal Energy Usage – Goods Vehicles**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Goods Vehicles	City Centre	Clifton	The Meadows	Colwick Park	St Ann's	Bestwood	Bulwell	Wollaton Park	Aspley	West Bridgford & South	Hucknall & North	Beeston & Kimberley	Ilkeston & Long Eaton	Arnold & East	External	Total	Origin Splits
1 City Centre	149,526	59,061	50,750	21,504	39,750	16,256	31,611	45,689	27,102	79,293	22,587	119,452	52,412	116,396	884,606	1,715,995	8%
2 Clifton	73,416	64,345	42,470	15,828	21,332	6,854	14,372	28,757	14,643	52,921	11,317	58,294	30,216	58,328	420,405	913,499	4%
3 The Meadows	33,789	22,822	27,573	9,929	11,691	3,501	5,973	8,510	4,707	22,509	4,071	21,086	9,794	24,190	292,218	502,364	2%
4 Colwick Park	20,414	12,087	14,208	8,025	7,832	2,330	4,022	5,331	2,967	14,608	2,708	13,673	6,408	16,173	141,131	271,919	1%
5 St Ann's	34,143	14,203	14,883	6,884	15,633	5,397	6,852	8,043	4,964	18,420	4,090	21,530	9,267	31,621	218,074	414,005	2%
6 Bestwood	14,583	4,838	4,859	2,202	5,779	3,975	6,022	4,950	3,304	7,512	2,705	16,090	5,970	20,948	105,340	209,077	1%
7 Bulwell	31,589	11,357	9,270	4,244	8,184	6,588	14,774	11,122	7,771	15,588	6,228	38,436	13,325	34,688	205,140	418,303	2%
8 Wollaton Park	45,392	22,410	12,873	5,499	9,424	5,370	10,880	24,132	10,202	20,516	7,020	40,185	20,638	34,842	270,355	539,739	2%
9 Aspley	24,239	10,156	6,345	2,721	5,176	3,204	6,840	9,182	7,815	10,202	3,924	23,966	10,234	19,670	152,667	296,340	1%
10 West Bridgford & South	391,346	211,016	169,549	76,433	111,713	44,509	83,027	111,294	62,703	404,354	66,868	313,211	162,149	341,418	977,395	3,526,985	16%
11 Hucknall & North	77,330	32,495	23,321	10,533	17,960	10,768	22,065	25,726	16,052	44,779	35,454	93,343	37,765	97,240	239,379	784,210	4%
12 Beeston & Kimberley	239,106	95,973	68,817	30,467	53,826	35,684	75,741	82,967	54,289	123,026	54,235	339,974	115,271	216,493	948,098	2,533,966	11%
13 Ilkeston & Long Eaton	139,787	66,482	43,085	19,190	31,442	18,421	36,716	57,182	31,884	85,064	29,284	154,387	135,378	118,207	501,345	1,467,855	7%
14 Arnold & East	257,799	106,744	86,225	39,360	82,812	48,675	76,331	81,006	50,655	150,263	62,433	239,614	98,373	386,248	1,026,165	2,792,702	13%
15 External	1,124,454	448,072	473,009	175,174	305,056	147,379	268,800	352,061	215,678	389,705	127,692	777,467	333,954	786,345	-	5,924,848	27%
Total	2,656,915	1,182,061	1,047,239	427,994	727,610	358,911	664,027	855,952	514,737	1,438,759	440,615	2,270,709	1,041,154	2,302,807	6,382,318	22,311,805	
Destination Splits	12%	5%	5%	2%	3%	2%	3%	4%	2%	6%	2%	10%	5%	10%	29%		

Table 29. **Zonal Energy Usage – Public Transport**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
All PT	City Centre	Clifton	The Meadows	Colwick Park	St Ann's	Bestwood	Bulwell	Wollaton Park	Aspley	West Bridgford & South	Hucknall & North	Beeston & Kimberley	Ilkeston & Long Eaton	Arnold & East	External	Total	Origin Splits
1 City Centre	-	49,137	-	7,581	12,178	32,794	48,357	20,077	11,622	96,356	-	39,104	40,250	156,665	258,156	772,278	39%
2 Clifton	49,137	-	-	-	-	-	-	-	-	-	-	-	-	13,351	-	62,488	3%
3 The Meadows	-	-	-	-	-	-	-	-	-	-	-	-	-	-	172,858	172,858	9%
4 Colwick Park	7,581	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,581	0%
5 St Ann's	12,178	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,178	1%
6 Bestwood	32,794	-	-	-	-	-	-	-	-	-	4,127	-	-	-	-	36,922	2%
7 Bulwell	48,357	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48,357	2%
8 Wollaton Park	20,077	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20,077	1%
9 Aspley	11,622	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11,622	1%
10 West Bridgford & South	82,620	-	-	-	-	-	-	-	-	13,736	-	-	-	-	-	96,356	5%
11 Hucknall & North	-	-	-	-	-	4,127	-	-	-	-	-	-	-	-	12,481	16,608	1%
12 Beeston & Kimberley	39,104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39,104	2%
13 Ilkeston & Long Eaton	40,250	-	-	-	-	-	-	-	-	-	-	-	-	-	17,898	58,149	3%
14 Arnold & East	156,665	13,351	-	-	-	-	-	-	-	-	-	-	-	-	-	170,016	9%
15 External	258,156	-	178,685	-	-	-	-	-	-	-	12,481	-	17,898	-	-	467,220	23%
Total	758,542	62,488	178,685	7,581	12,178	36,922	48,357	20,077	11,622	110,093	16,608	39,104	58,149	170,016	461,394	1,991,814	
Destination Splits	38%	3%	9%	0%	1%	2%	2%	1%	1%	6%	1%	2%	3%	9%	23%		

5.3.9 Table 30 shows the energy usage for buses and trains within Nottingham, including energy per passenger and per vehicle km.

Table 30. **PT Energy Usage By Vehicle Type**

ROUTE NO	TOTAL ENERGY	SERVICES	ROUTE LENGTH (KM)	VEHICLE KMS	ENERGY/ VEHKMS	ENERGY/ PASS
Buses	1,640,271	8,398	754.8	119,648	13.71	4.29
Tram	-	408	12.5	5,081	0.00	0.00
Train	351,543	495	495.3	19,254	18.26	6.65
Total	**1,991,814**	**9,301**	**1262.6**	**143,983**	**13.83**	**4.16**

5.4 Emissions Outputs

5.4.1 This section of the report looks at other emissions calculated by the model. These include;

- Nitrous Oxides;
- Particulate Matter (PM10s);
- Hydro Carbons;
- Carbon Monoxide; and
- Carbon Dioxide.

5.4.2 Figure 24 shows the Carbon Dioxide Emissions split into Vehicle Type. These splits are very similar to the Energy Usage splits.

5.4.3 Figure 25 shows the Vehicle Type splits for the other Emissions types. It can be seen that the splits here are very different to the Carbon Dioxide splits, shown on the far right. Mopeds and Motorbikes are more responsible for Hydro-Carbons, PM10s and Carbon Monoxide.

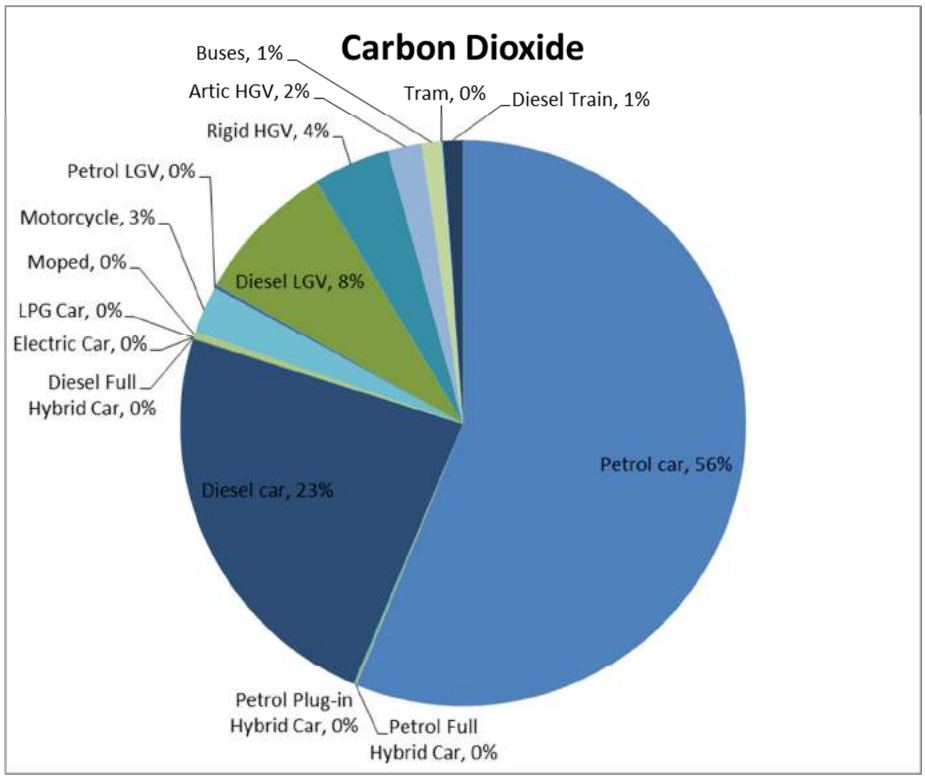

Figure 24. Carbon Dioxide Emissions By Vehicle Type

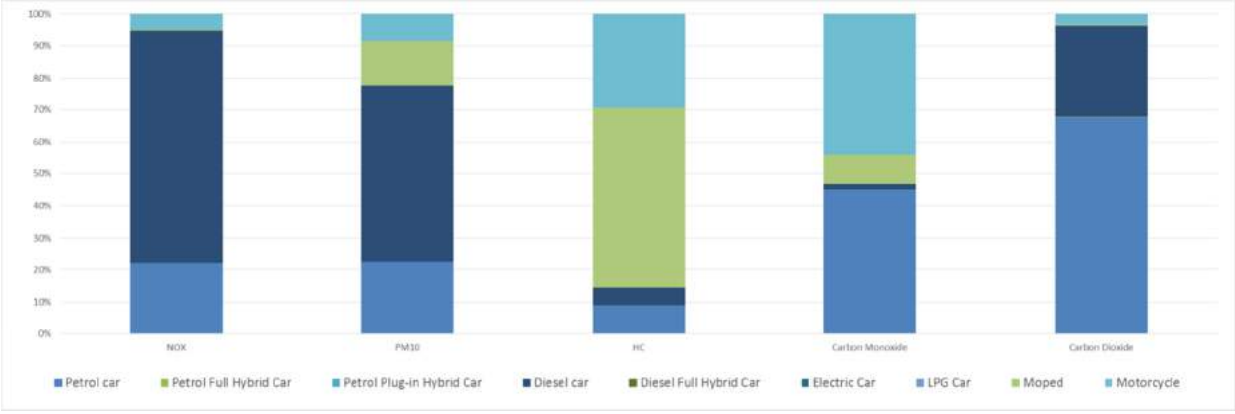

Figure 25. Emissions by Vehicle Type

Table 31. **Emissions By Vehicle Type (kg)**

VEHICLE TYPE	NOX	PM10	HCS	CO	CO2
Petrol car	1,859.728	99.064	629.295	21,005.029	6,415,306.367
Petrol Full Hybrid Car	3.125	0.296	0.871	38.825	10,468.741
Petrol Plug-in Hybrid Car	2.031	0.181	0.839	36.944	10,073.408
Diesel car	6,127.134	242.961	358.842	898.776	2,676,787.563
Diesel Full Hybrid Car	17.030	0.575	0.846	1.835	6,402.473
Electric Car	-	-	-	-	-
LPG Car	3.752	0.038	0.813	1.570	3,059.149
Moped	15.943	62.278	3,866.212	4,384.364	39,620.709
Motorcycle	423.370	37.654	2,021.865	20,698.587	311,843.787
Petrol LGV	8.558	0.138	3.538	180.472	22,249.985
Diesel LGV	1,976.268	87.769	103.264	555.277	934,733.487
Rigid HGV	2,162.687	28.906	51.631	322.755	503,478.220
Artic HGV	979.850	12.523	20.792	91.612	221,926.409
Buses	659.020	9.907	21.275	99.835	123,724.126
Tram	-	-	-	-	10,954.454
Diesel Train	-	-	-	-	132,911.743
Total	**14,238.498**	**582.290**	**7,080.084**	**48,315.882**	**11,423,540.622**
Cars	8,012.801	343.116	991.506	21,982.979	9,122,097.701
Bikes	439.314	99.932	5,888.078	25,082.952	351,464.496
Goods	5,127.363	129.336	179.225	1,150.117	1,682,388.101
Buses	659.020	9.907	21.275	99.835	123,724.126
Trams	-	-	-	-	10,954.454
Trains	-	-	-	-	132,911.743

WP3 – Transport and Mobility Analysis

D.3.2. Transport Base Year Report Trikala

October 2015

314164 (ENER/FP7/314164)

Project acronym:

InSMART

Project full title:

Integrative Smart City Planning

Coordination and support action (Coordinating Action)

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Start date of project: 2013-12-01

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Deliverable D3.2.

Transport Base Year Report Trikala

Work Package 3. Transport and Mobility Analysis

October 2015

Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Executive Summary	
This report presents the results of the Baseline Scenario of the transport model that has been developed in the framework of the INSMART project for the city of Trikala.	
Keywords	Transport scenarios




BASE YEAR REPORT - TRIKALA

INSMART – INTEGRATIVE SMART CITY PLANNING

BASE YEAR REPORT - TRIKALA

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1. INTRODUCTION

1.1 Project Overview

1.1.1 InSmart is a three year, European funded project which involves four European Cities working in partnership towards a sustainable energy future. The primary objective of the project is to develop sustainable energy action plans for each partner city.

1.1.2 The four cities are;

- Cesena, Italy;
- Evora, Portugal;
- Nottingham, UK; and
- Trikala, Greece.

1.1.3 A mix of sustainable energy measures to improve the energy efficiency of each city will be identified through the use of a variety of tools and approaches. This will cover a wide range of sectors from the residential and transport sectors, to street lighting and waste collection.

1.1.4 SYSTRA's role within the project is to identify, test and report on a series of land use and transport based strategies aimed at reducing the transport-related energy usage and carbon generation of each city.

1.1.5 The initial task is to calculate the current energy usage and carbon emissions generated by each city. The impact of the forecast strategies can then be obtained by a comparison with the base figures.

1.2 Trikala

1.2.1 This report covers the City of Trikala in northwestern Thessaly, Greece.

1.2.2 The city of Trikala is the capital of the Trikala regional area, situated some 330 km northwest of Athens.

1.2.3 The city has been split into 20 zones, as shown in Figure 1. In addition the model has a 21st zone covering the area external to the 20 internal zones – allowing for travel to and from the city.

1.2.4 The city has also been split into 5 Area Types representing different areas of the city. These are;

- City Centre;
- Edge of City Centre;
- Sub0Urban areas;
- Rural/Outside City; and
- External

1.2.5 Some inputs, such as vehicle speeds, are at this more aggregate level of detail. The Area Type allocation is shown in Figure 2.

1.3 Report Structure

1.3.1 The report is split into four sections;

- Executive Summary/Conclusions – the key aspects of the Base Year model outputs;
- Inputs – covering all the city-specific inputs;
- Calibration – details of model calibration to observed mode share and trip length information; and
- Outputs – details of demand movements, energy consumption and emissions.

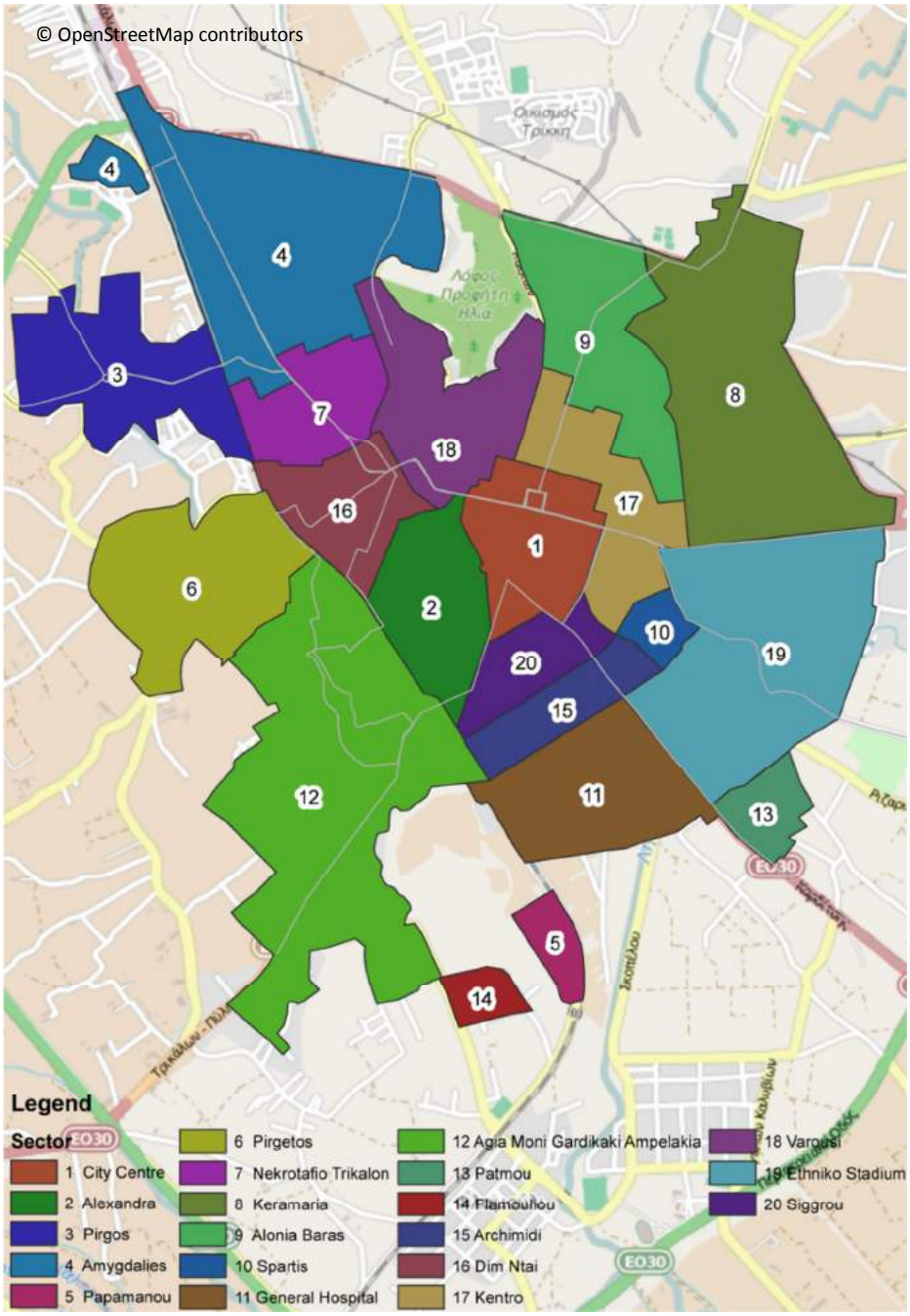


Figure 1. Trikala Zoning System

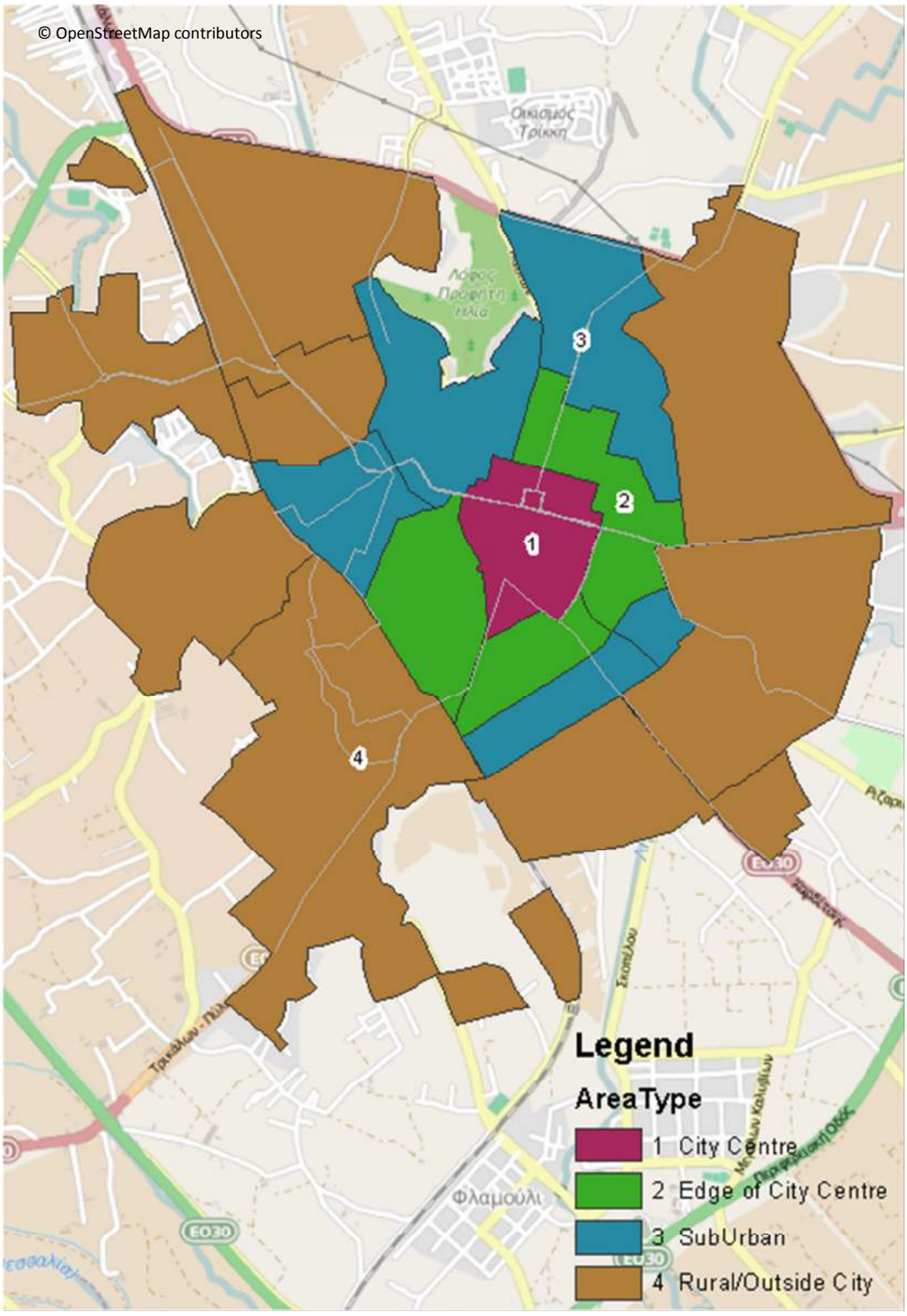


Figure 2. Trikala Area Types

2. EXECUTIVE SUMMARY/CONCLUSIONS

2.1 Introduction

2.1.1 This section of the report aims to summarise the key aspects of the model outputs from the base year model run. They can be split into three different types of outputs:

- Demand Outputs;
- Energy Consumption Outputs; and
- Emissions Outputs.

2.1.2 A more detailed analysis of these outputs is presented in the main outputs section.

2.2 Demand Outputs

2.2.1 The total person demand in Trikala is 178,091, which using average city-specific vehicle occupancies, equates to around 130,476 vehicles. This is on average 2.9 trips per person, with an average distance of 1.5km. Figure 3 shows the number of vehicles broken down by type, with Petrol Cars making up almost two thirds of the total vehicle demand.

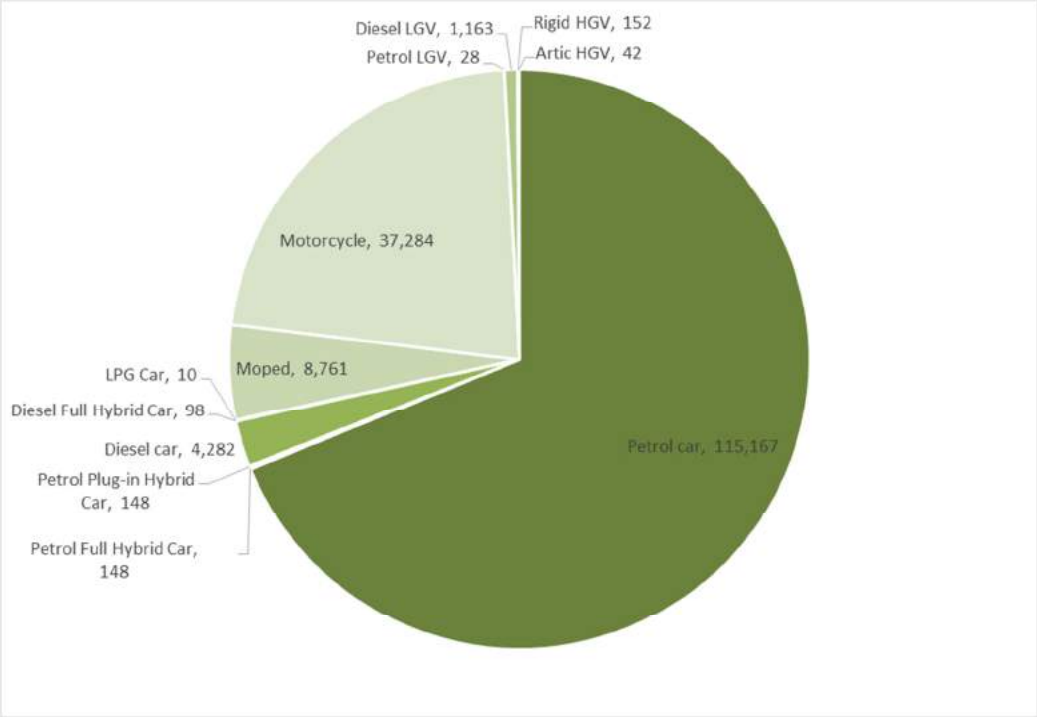


Figure 3. Demand By Vehicle Type

2.3 Energy Consumption Outputs

2.3.1 Table 1 presents a summary of the total energy used by transport within Trikala. The total daily value across all modes, vehicle types, purposes and zones is **934,855 MJ**, which is around 15MJ per person, per day.

2.3.2 It can be seen that more than half of the total energy used by transport in Trikala can be attributed to cars, which represent roughly just over a half of the total demand.

Table 1. Energy Usage Summary

NO	TOTAL	CARS	BIKES	GOODS	BUSES	TRAINS
Total Energy (MJ)	**934,855**	**625,389**	**230,646**	**11,960**	**62,150**	**4,711**
Population	62,154					
Energy Per Person (MJ)	15.0	10.1	3.7	0.2	1.0	0.1
Demand (Persons)	178,091	119,852	46,045	1,385	10,798	11
Energy Per Trip (MJ)	5.2	5.2	5.0	8.6	5.8	410.0
Trips Per Person	2.9	1.9	0.7	0.0	0.2	0.0
Actual Vehicles	54,132	31,036	22,729	249	106	12
Energy Per Vehicle (MJ)	17.3	20.2	10.1	48.1	585.1	392.5
Vehicles Per Person	0.87	0.50	0.37	0.00	0.00	0.000

2.3.3 Figure 4 shows the energy consumption aggregated to the zone the demand originates in. It can be seen that zones furthest from the city centre (where the highest numbers of attractions are), often have a high energy usage due to the larger trip lengths. Whereas zones closer to the centre, often have a low energy usage from the shorter trip lengths. The zones with the lowest energy usage are the smallest four zones.

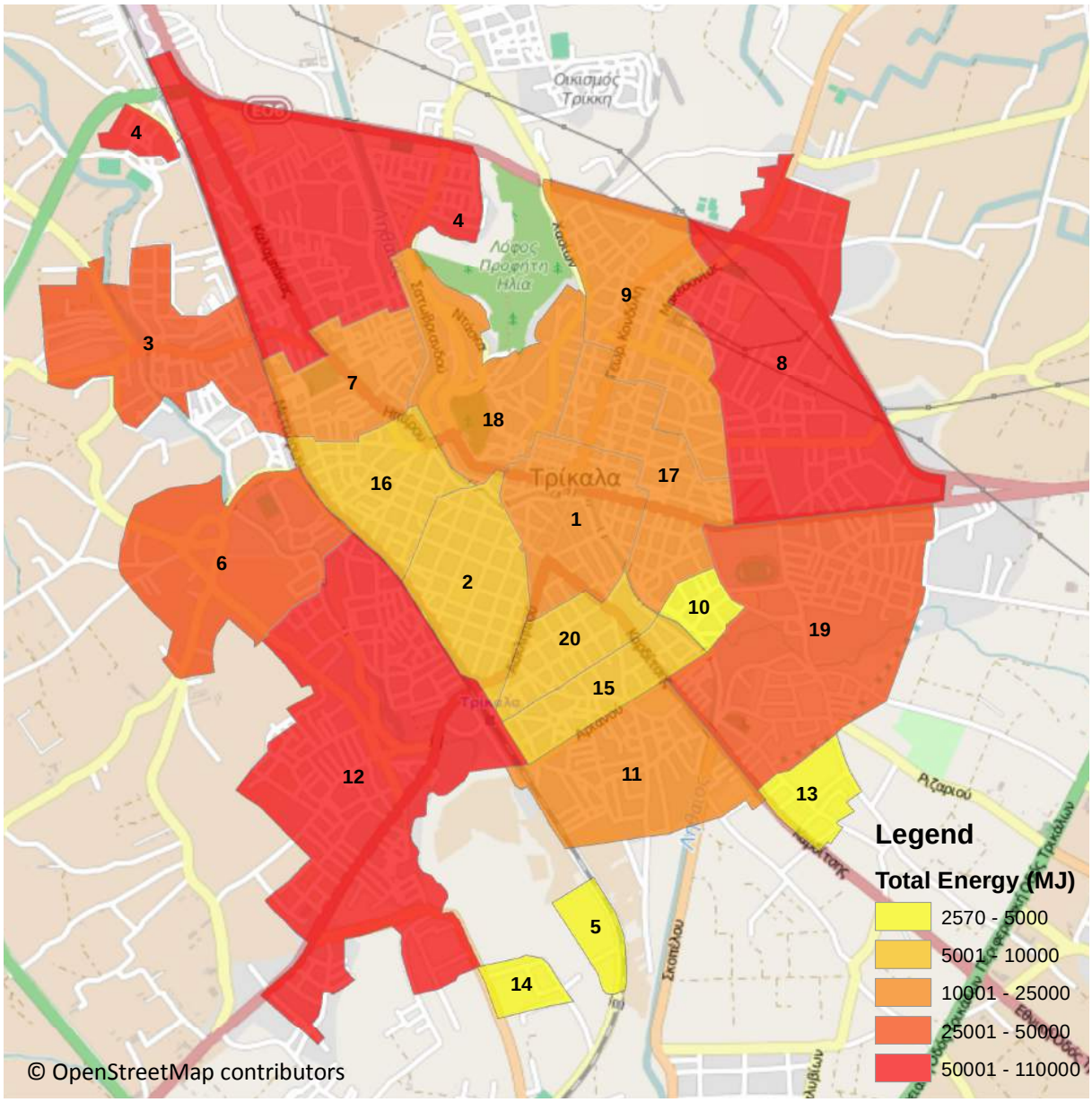


Figure 4. Total Energy (MJ) Per Origin Zone

2.4 Emissions Outputs

2.4.1 The model also reports the following emissions;

- Nitrous Oxides;
- Particulate Matter (PM10s);
- Hydro Carbons;
- Carbon Monoxide; and
- Carbon Dioxide.

2.4.2 Figure 5 demonstrates each of the emission types and the contribution each vehicle type has upon each emission. It can be seen that the splits here are very different depending on the emission type. Mopeds and Motorbikes are responsible for most of the Hydro-Carbons, PM10s and Carbon Monoxide emitted despite being only a small percentage of the total demand.

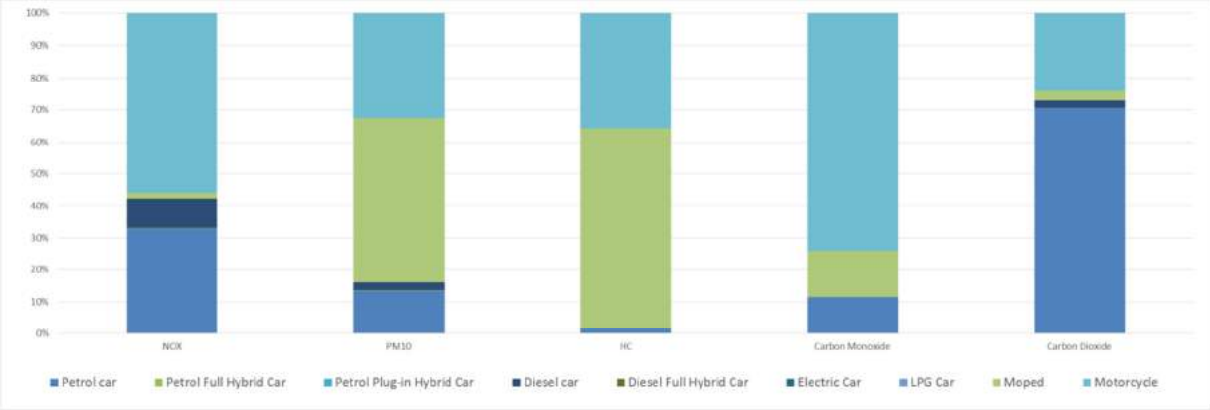


Figure 5. Emissions by Vehicle Type

3. INPUTS

3.1 Introduction

3.1.1 The inputs to the model can be broken down into three sets;

- Model specific inputs such as zoning, distances, public transport services, land use;
- Inputs common to all models such as trip purposes, vehicle types, modes etc;
- Parameters for the energy and emissions calculations and for the various transport choices (mode, destination, route).

3.1.2 This report covers only the first set – model specific inputs. In the following sections information is given on the main model-specific inputs and their sources. Inputs included are;

- Land Use – Residential and Non-Residential;
- Public Transport Routes;
- Distances;
- Speeds;
- Purpose Splits;
- Vehicle Type Splits;
- Public Transport Fares;
- Parking Charges; and
- Internal/External Demand splits.

3.2 Land Use

3.2.1 The land use is one of the most important inputs in the model. The number of dwellings, split into houses and flats, is multiplied by an average trip rate to give a total number of home-based trips per zone. These trips are then distributed amongst the non-residential land use locations based on journey time and the relative attractiveness and size of the non-residential attractors.

Residential

3.2.2 The number of houses and flats in each zone was calculated using the following process;

- Spread the total number of residential dwellings in Trikala (29,055) based on the population in each zone;
- Calculate the split between houses and flats by zone from the building survey information; and
- Apply the house/flat splits to the total number of dwellings in each zone.

3.2.3 The average occupancy per zone was checked and was found to be 2.14 persons per dwelling for the entire Trikala modelled area.

3.2.4 Table 2 shows the population and number of houses and flats by zone. Figure 6 shows the same information graphically.

Table 2. Population and Residential Land Use

NO	ZONE NAME	POP	HOUSES	FLATS	TOTAL	AVE OCC
1	City Centre	2,537	96	1,090	1,186	
2	Alexandra	2,473	92	1,064	1,156	
3	Pirgos	3,491	1,632	-	1,632	
4	Amygdalies	7,323	3,069	354	3,423	
5	Papamanou	527	246	-	246	
6	Pirgetos	4,031	1,346	538	1,884	
7	Nekrotafio Trikalon	1,995	932	-	932	
8	Keramaria	6,917	3,234	-	3,234	
9	Alonia Baras	3,434	185	1,420	1,605	
10	Spartis	506	172	64	236	
11	General Hospital	2,974	1,390	-	1,390	
12	Agia Moni Gardikaki Ampelakia	9,422	4,221	184	4,405	
13	Patmou	644	301	-	301	
14	Flamouliou	364	170	-	170	
15	Archimidi	1,417	309	353	662	
16	Dim Ntai	2,042	91	864	955	
17	Kentro	2,599	28	1,187	1,215	
18	Varousi	2,860	836	501	1,337	
19	Ethniko Stadium	5,222	1,867	574	2,441	
20	Siggrou	1,378	86	558	644	
	Total	**62,154**	**20,303**	**8,752**	**29,055**	**2.14**

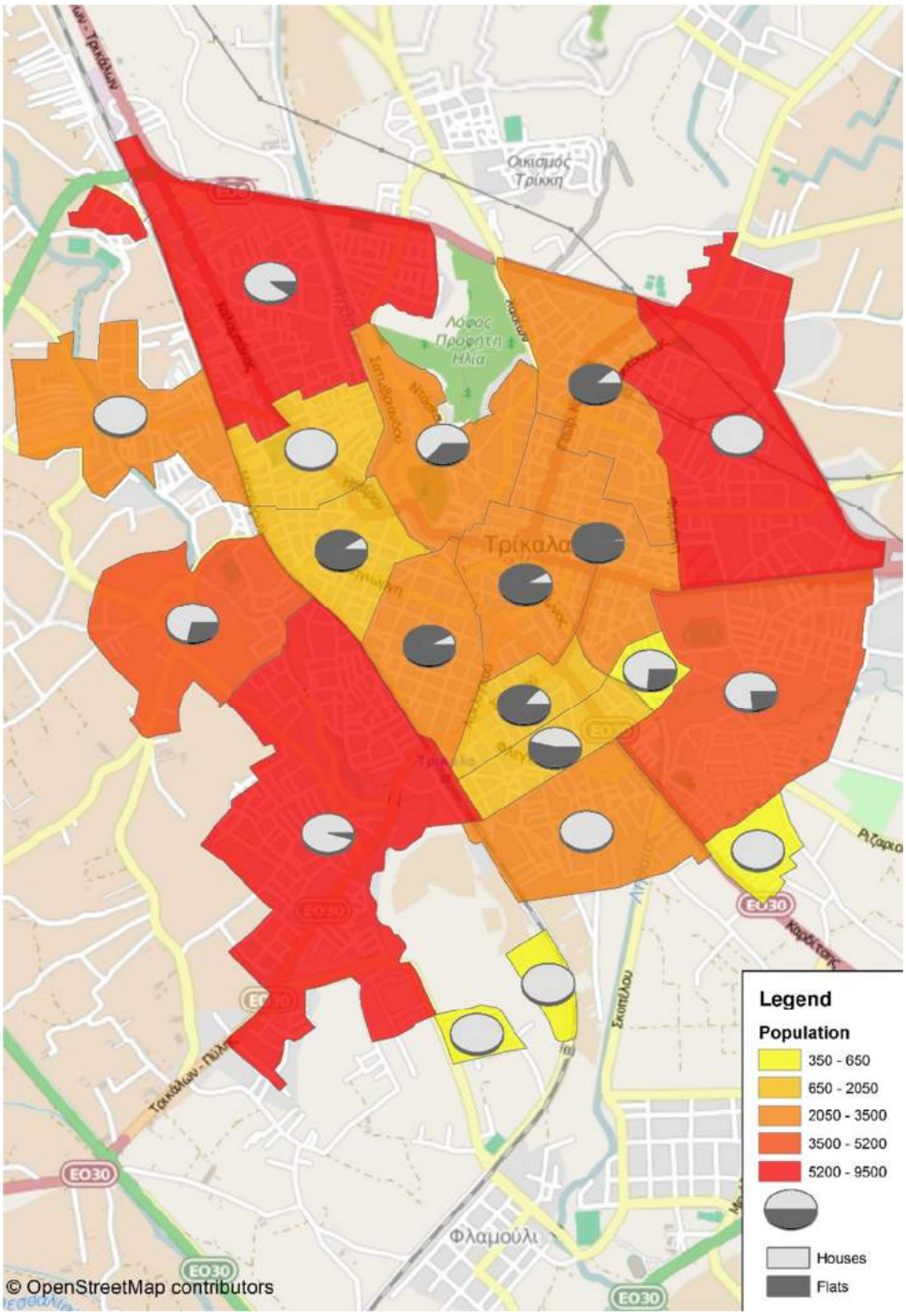


Figure 6. Population and Household Type Splits

Non-Residential:

3.2.5 Table 3 shows the non-residential land use. The data is input to the model at a more disaggregate level, but is summarised here for clarity. The groupings also reflect the data received – which was both sub-categories of Employment. Full details of the assumed land use splits can be found in Appendix A. The following text provides information on how the data was split.

3.2.6 **Employment**: The employment floorspace was split into Office and Other. The values for both were provided, with the "Other" employment allocated as Industrial Land Use.

3.2.7 **Retail, Education and Other**: Splits between these three Land Uses were identified through a GIS process.

Table 3. Non-Residential Land Use

NO	ZONE NAME	WORK	SHOPPING	EDUCATION	OTHER
1	City Centre	45,264	1,024	-	12,102
2	Alexandra	2,700	2,200	-	1,091
3	Pirgos	-	-	-	-
4	Amygdalies	1,493	3,276	-	-
5	Papamanou	-	-	-	-
6	Pirgetos	-	-	-	-
7	Nekrotafio Trikalon	4,297	5,742	-	-
8	Keramaria	-	-	-	-
9	Alonia Baras	1,200	-	50,706	-
10	Spartis	-	-	-	-
11	General Hospital	-	10,626	-	39,328
12	Agia Moni Gardikaki Ampelakia	29,071	6,030	-	7,445
13	Patmou	6,558	-	-	-
14	Flamouliou	-	-	-	-
15	Archimidi	-	-	-	-
16	Dim Ntai	100	-	-	-
17	Kentro	6,200	-	-	1,232
18	Varousi	1,200	-	3,496	-
19	Ethniko Stadium	25,292	19,591	-	-
20	Siggrou	800	-	3,596	-
	Total	**124,175**	**48,489**	**57,798**	**61,198**

3.2.8 Figure 4 shows the land use figures as percentages of the total zonal land use.

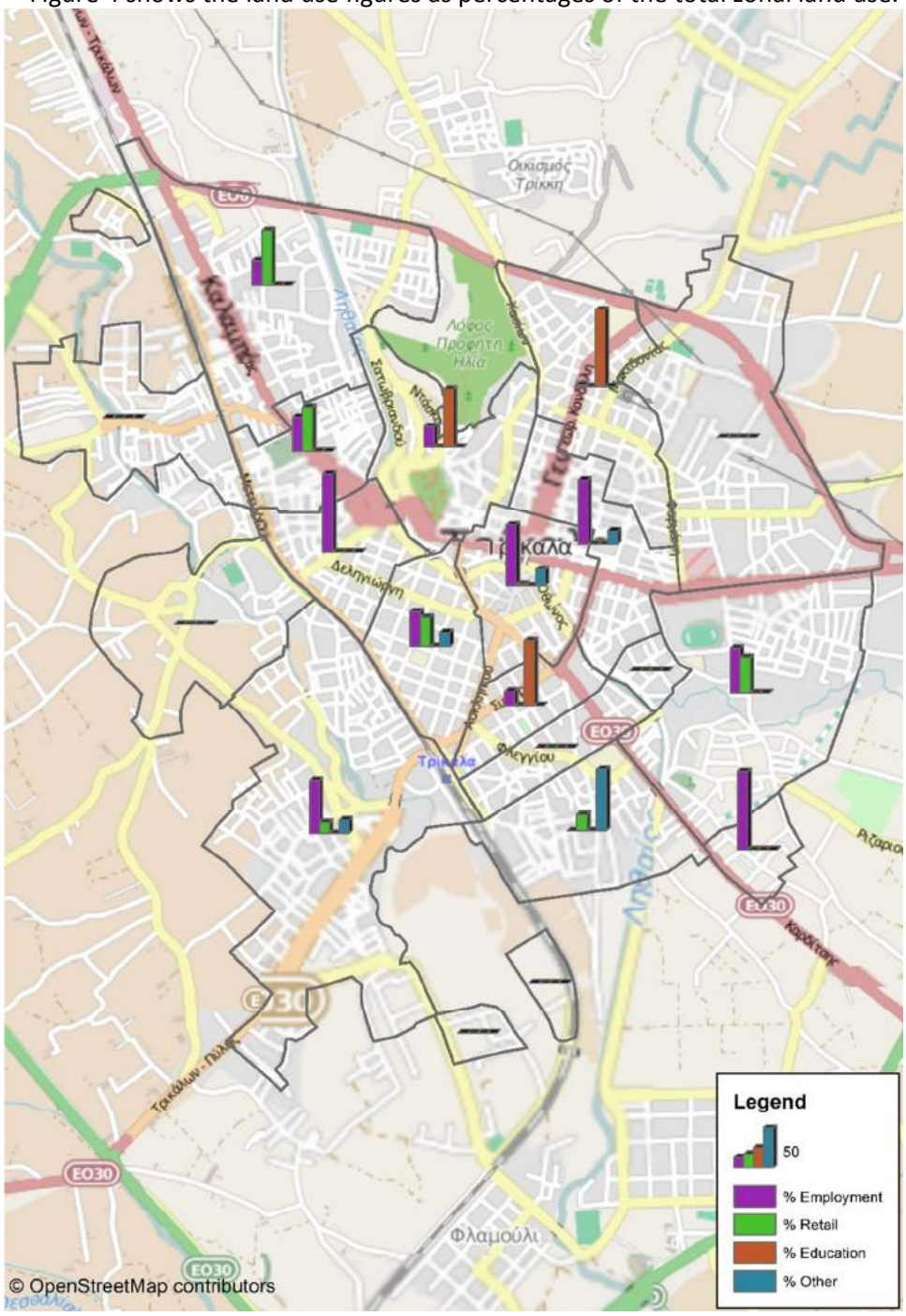


Figure 7. Percentage Land Use by Zone

3.3 Distances

3.3.1 The model calculates average travel times between zones using the average zone-zone distance and speeds. These distances have been obtained via an online routing service, choosing the most common route between the centre of each zone. The public transport distances follow the bus and rail service routes.

3.3.2 Figure 8 shows the Highway routes used, with the route between zones 1 and 2 highlighted as an example. For the highway all movements are possible between all origin-destination combinations. As the Public transport distances have to follow Public Transport routes there are some movements where travel is not possible, and so no distance exists. This is particularly true for rail where the only movement is from zone 2 to the external zone 21.

3.3.3 Distances to the external zone are taken as the average distance from the Transport Survey to locations outside the study area.

3.3.4 Table 4 to Table 6 show the input distance matrices for highway, bus and rail respectively.

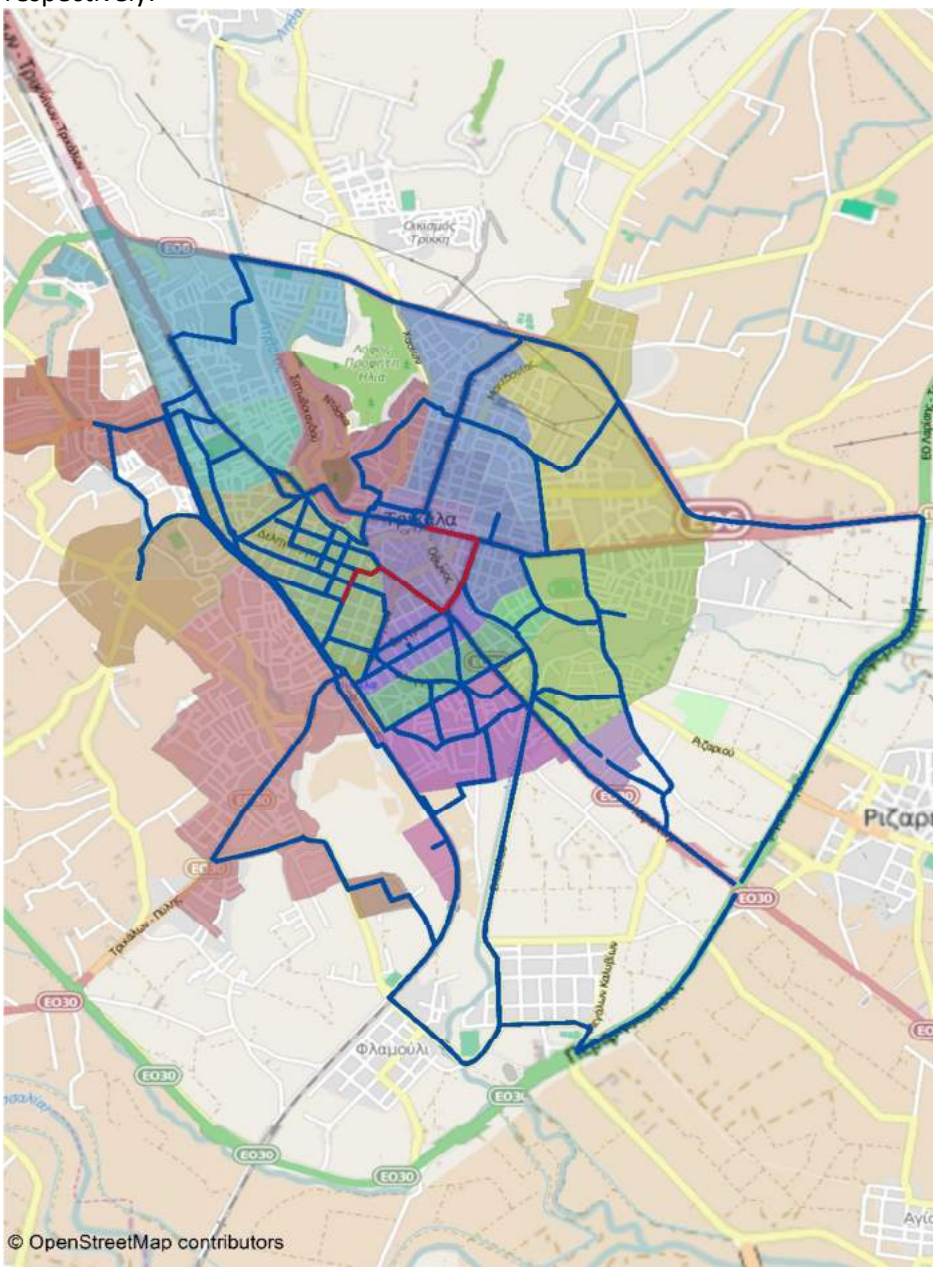


Figure 8. Highway Distances

Table 4. Highway Distances (Km)

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.6	2.1	2.8	3.0	3.8	4.2	1.7	2.2	1.2	1.4	2.4	2.9	2.9	4.4	2.3	1.4	0.7	0.9	1.9	1.6	24.2
2	2.1	0.6	2.7	3.2	2.3	2.2	1.8	3.7	2.7	2.6	2.1	1.4	3.2	2.9	1.3	1.1	2.2	1.5	3.4	1.1	24.2
3	2.8	2.7	0.7	2.1	4.7	0.8	1.3	5.1	4.1	4.3	4.8	3.8	5.7	5.3	4.0	2.2	3.7	3.0	4.9	3.8	24.2
4	3.0	3.2	2.1	0.8	5.3	3.1	1.6	4.0	3.3	4.5	5.2	4.5	6.0	6.0	4.5	2.6	3.9	3.2	5.1	4.3	24.2
5	3.8	2.3	4.7	5.3	0.8	4.0	3.8	5.2	4.9	3.9	1.1	2.1	2.3	0.9	2.5	3.3	3.6	3.8	4.8	2.3	24.2
6	4.2	2.2	0.8	3.1	4.0	0.7	2.3	5.3	4.3	4.5	4.3	3.1	5.2	4.6	3.6	1.8	3.8	3.2	5.1	3.4	24.2
7	1.7	1.8	1.3	1.6	3.8	2.3	0.5	4.0	3.0	3.2	4.2	2.9	4.7	4.4	3.1	1.0	2.5	1.9	3.7	2.9	24.2
8	2.2	3.7	5.1	4.0	5.2	5.3	4.0	0.8	1.5	2.2	4.0	4.5	3.7	3.8	3.8	3.8	2.1	2.4	2.4	3.2	24.2
9	1.2	2.7	4.1	3.3	4.9	4.3	3.0	1.5	0.6	2.7	3.8	4.3	4.3	4.2	3.6	2.6	2.1	1.4	2.7	3.0	24.2
10	1.4	2.6	4.3	4.5	3.9	4.5	3.2	2.2	2.7	0.6	1.3	2.9	1.5	1.6	1.5	2.9	1.1	2.3	0.9	1.7	24.2
11	2.4	2.1	4.8	5.2	1.1	4.3	4.2	4.0	3.8	1.3	0.5	2.1	1.3	1.7	1.0	3.1	2.3	3.2	2.2	1.4	24.2
12	2.9	1.4	3.8	4.5	2.1	3.1	2.9	4.5	4.3	2.9	2.1	0.7	3.2	2.8	1.6	2.4	2.7	3.8	3.9	1.4	24.2
13	2.9	3.2	5.7	6.0	2.3	5.2	4.7	3.7	4.3	1.5	1.3	3.2	0.6	1.6	2.1	3.3	2.6	3.5	2.4	2.3	24.2
14	4.4	2.9	5.3	6.0	0.9	4.6	4.4	3.8	4.2	1.6	1.7	2.8	1.6	0.8	3.1	3.9	4.3	5.3	2.5	2.9	24.2
15	2.3	1.3	4.0	4.5	2.5	3.6	3.1	3.8	3.6	1.5	1.0	1.6	2.1	3.1	0.5	3.1	2.2	3.2	2.6	1.0	24.2
16	1.4	1.1	2.2	2.6	3.3	1.8	1.0	3.8	2.6	2.9	3.1	2.4	3.3	3.9	3.1	0.5	2.1	1.4	3.3	2.4	24.2
17	0.7	2.2	3.7	3.9	3.6	3.8	2.5	2.1	2.1	1.1	2.3	2.7	2.6	4.3	2.2	2.1	0.6	1.6	1.7	1.5	24.2
18	0.9	1.5	3.0	3.2	3.8	3.2	1.9	2.4	1.4	2.3	3.2	3.8	3.5	5.3	3.2	1.4	1.6	0.7	2.9	2.6	24.2
19	1.9	3.4	4.9	5.1	4.8	5.1	3.7	2.4	2.7	0.9	2.2	3.9	2.4	2.5	2.6	3.3	1.7	2.9	1.0	2.6	24.2
20	1.6	1.1	3.8	4.3	2.3	3.4	2.9	3.2	3.0	1.7	1.4	1.4	2.3	2.9	1.0	2.4	1.5	2.6	2.6	0.6	24.2
21	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	24.2	0

Table 5. Bus Distances (Km)

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.2	2.1	2.8	2.6	0.0	3.6	1.6	1.2	1.1	1.2	2.0	3.1	2.8	0.0	1.5	1.3	0.5	0.8	1.7	1.1	21.5
2	2.1	0.8	4.5	4.2	0.0	1.5	3.2	4.8	4.8	4.8	5.6	2.0	6.4	0.0	5.1	2.3	4.1	2.7	5.3	4.7	21.5
3	2.8	4.5	0.4	1.8	0.0	2.9	1.3	4.2	4.2	4.2	5.0	6.1	5.8	0.0	4.5	2.2	3.5	2.1	4.7	4.1	21.5
4	2.6	4.2	1.8	0.5	0.0	2.7	1.1	3.9	4.0	4.0	4.8	5.8	5.5	0.0	4.2	2.0	3.2	1.9	4.5	3.9	21.5
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
6	3.6	1.5	2.9	2.7	0.0	0.4	1.7	3.3	3.3	3.3	4.1	2.5	4.9	0.0	3.6	0.7	2.6	1.2	3.8	3.2	0
7	1.6	3.2	1.3	1.1	0.0	1.7	0.4	2.9	2.9	2.9	3.7	4.8	4.5	0.0	3.2	0.9	2.2	0.8	3.4	2.8	21.5
8	1.2	4.8	4.2	3.9	0.0	3.3	2.9	0.3	2.5	0.9	2.4	3.6	3.1	0.0	1.8	2.5	0.7	2.1	1.4	1.5	21.5
9	1.1	4.8	4.2	4.0	0.0	3.3	2.9	2.5	0.5	2.6	3.4	4.5	4.1	0.0	2.9	2.5	1.8	2.0	3.1	2.5	21.5
10	1.2	4.8	4.2	4.0	0.0	3.3	2.9	0.9	2.6	0.2	2.5	3.5	3.2	0.0	1.9	2.8	0.7	2.3	0.5	1.6	21.5
11	2.0	5.6	5.0	4.8	0.0	4.1	3.7	2.4	3.4	2.5	0.1	3.0	0.8	0.0	0.5	3.6	1.7	3.1	2.9	0.9	21.5
12	3.1	2.0	6.1	5.8	0.0	2.5	4.8	3.6	4.5	3.5	3.0	0.0	3.8	0.0	2.5	3.2	2.9	4.3	4.1	2.1	21.5
13	2.8	6.4	5.8	5.5	0.0	4.9	4.5	3.1	4.1	3.2	0.8	3.8	0.1	0.0	1.3	4.3	2.4	3.8	3.6	1.7	21.5
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
15	1.5	5.1	4.5	4.2	0.0	3.6	3.2	1.8	2.9	1.9	0.5	2.5	1.3	0.0	0.2	3.0	1.1	2.6	2.4	0.4	21.5
16	1.3	2.3	2.2	2.0	0.0	0.7	0.9	2.5	2.5	2.8	3.6	3.2	4.3	0.0	3.0	0.2	1.8	0.5	3.1	2.5	21.5
17	0.5	4.1	3.5	3.2	0.0	2.6	2.2	0.7	1.8	0.7	1.7	2.9	2.4	0.0	1.1	1.8	0.2	1.6	1.2	0.8	21.5
18	0.8	2.7	2.1	1.9	0.0	1.2	0.8	2.1	2.0	2.3	3.1	4.3	3.8	0.0	2.6	0.5	1.6	0.2	2.6	2.0	21.5
19	1.7	5.3	4.7	4.5	0.0	3.8	3.4	1.4	3.1	0.5	2.9	4.1	3.6	0.0	2.4	3.1	1.2	2.6	0.2	2.0	21.5
20	1.1	4.7	4.1	3.9	0.0	3.2	2.8	1.5	2.5	1.6	0.9	2.1	1.7	0.0	0.4	2.5	0.8	2.0	2.0	0.1	21.5
21	21.5	21.5	21.5	21.5	0	0	21.5	21.5	21.5	21.5	21.5	21.5	21.5	0	21.5	21.5	21.5	21.5	21.5	21.5	0

Table 6. Rail Distances (Km)

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.5
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
21	0	21.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.4 Public Transport Routes

3.4.1 The main 11 bus routes in Trikala are included in the model. Figure 9 shows the routes that the services follow. Table 7 gives details of the routes included and the number of buses per day.

3.4.2 In addition to the bus services there is a train service from zone 2 to the external zone 21. Technically the station is located on the boundary between zones 2 and 12. It has been allocated to zone 2 due to the better accessibility to buses.

3.4.3 Public Transport demand is allowed to take any route that is either direct, or involves one transfer. The route choice model then spreads the demand amongst all the possible routes for a given movement based on the generalised cost of the journey (made up of travel time, wait time, walking time, fare etc).

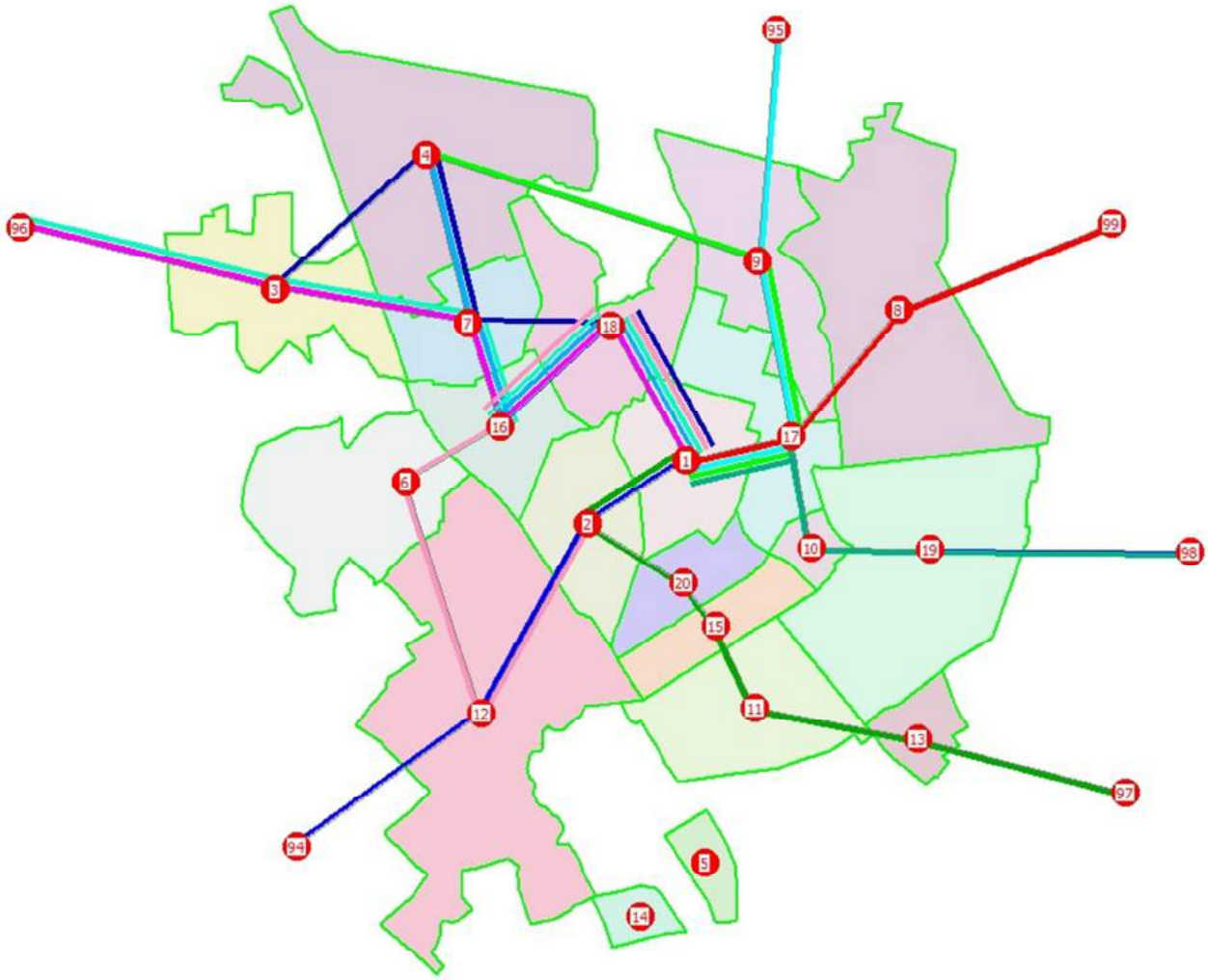


Figure 9. Public Transport Routes

Table 7. Public Transport Routes

ROUTE NO	FROM	TO	ZONE FROM	ZONE TO	BUSES PER DAY
1	Trikala	Ag. Moni	1	12	50
2	Trikala	Kalyvia - TEFAA	1	21	14
3	Trikala	Megaloxori	1	21	22
4	Trikala	Loggaki	1	21	16
5	Trikala	Ag. Oikoumenios	1	4	38
6	Trikala	Dialechto - Mikro Kefalovriso	1	21	10
7	Trikala	Megalo Kefalovryso	1	4	18
8	Trikala	Dendroxori - Valtino	1	21	13
A	Trikala	Pyrgetos	1	12	7
B	Trikala	Rizario	1	21	15
C	Trikala	Pyrgos - OAED	1	3	36

3.5 Speeds

3.5.1 The speeds in the model are specified by Vehicle Type and Area Type. Table 8 shows the speeds used in the model, aggregated to groups of vehicle types with the same sets of speed. The groupings are;

- Cars: Petrol, Diesel, Petrol Full Hybrid, Diesel Full-Hybrid, Electric, LPG cars and Taxis;
- Goods Vehicles: Petrol and Diesel LGVs, Rigid and Artic HGVs;
- Buses: Diesel, Hybrid, Electric and Gas-powered buses; and
- Trains: Diesel and Electric trains.

Table 8. Speeds by Vehicle and Area Type (Km/h)

VEHICLE TYPE	CITY CENTRE	EDGE OF CITY CENTRE	SUBURBAN	RURAL/ OUTSIDE CITY	EXTERNAL
Cars	50	50	50	70	70
Goods Vehicles	40	40	40	50	50
Buses	50	50	50	70	70
Mopeds/Motorbikes	30	30	40	70	90
Trains	90	90	90	90	90

3.6 Purpose Splits

3.6.1 The home-based trips are split into purposes using zonal purpose splitting factors. These have been calculated from the Transport Survey data. For the Retail and Education purposes where the percentage split was less than the average for the whole city the average split was used. The Work and Other purposes were then factored down to retain 100% across all purposes.

3.6.2 Table 9 shows the zonal purpose splits used, with Figure 10 showing the variation graphically. Figure 11 shows the average purpose splits across the whole city. “Other” trips make up a very large proportion of the trips – almost two thirds.

Table 9. Residential Purpose Splits

Zone	Office	Industry / Warehousing	Retail Food	Retail Non-Food	Primary School	Secondary School	College	Other	All Purposes
1 City Centre	7%	2%	1%	4%	0%	1%	0%	85%	100%
2 Alexandra	11%	3%	1%	4%	0%	1%	0%	81%	100%
3 Pirgos	16%	5%	2%	9%	0%	2%	0%	66%	100%
4 Koutsouflianis	22%	6%	1%	5%	0%	1%	0%	65%	100%
5 Papamanou	17%	5%	1%	5%	1%	3%	0%	68%	100%
6 Pirgetos	25%	7%	1%	4%	0%	1%	0%	62%	100%
7 Nekrotafio Trikalon	11%	3%	1%	4%	0%	1%	0%	80%	100%
8 Mavili	28%	8%	1%	4%	0%	1%	0%	59%	100%
9 Paleologou	21%	6%	1%	4%	1%	6%	0%	61%	100%
10 Spartis	2%	1%	1%	4%	0%	1%	0%	92%	100%
11 General Hospital	17%	5%	1%	6%	0%	1%	0%	70%	100%
12 Train Station	20%	6%	2%	8%	0%	1%	0%	64%	100%
13 Patmou	5%	2%	1%	4%	0%	1%	0%	88%	100%
14 Flamouliou	19%	6%	5%	20%	0%	1%	0%	49%	100%
15 Archimidi	14%	4%	4%	15%	0%	1%	0%	61%	100%
16 Dim Ntai	17%	5%	3%	11%	0%	1%	0%	63%	100%
17 Sokratous	13%	4%	1%	4%	0%	1%	0%	77%	100%
18 Castle	25%	7%	1%	4%	0%	1%	0%	63%	100%
19 Ethniko Stadio	23%	7%	1%	4%	1%	2%	0%	63%	100%
20 Siggrou	16%	5%	1%	4%	0%	1%	0%	74%	100%
Average	16%	5%	1%	4%	0%	1%	0%	74%	100%

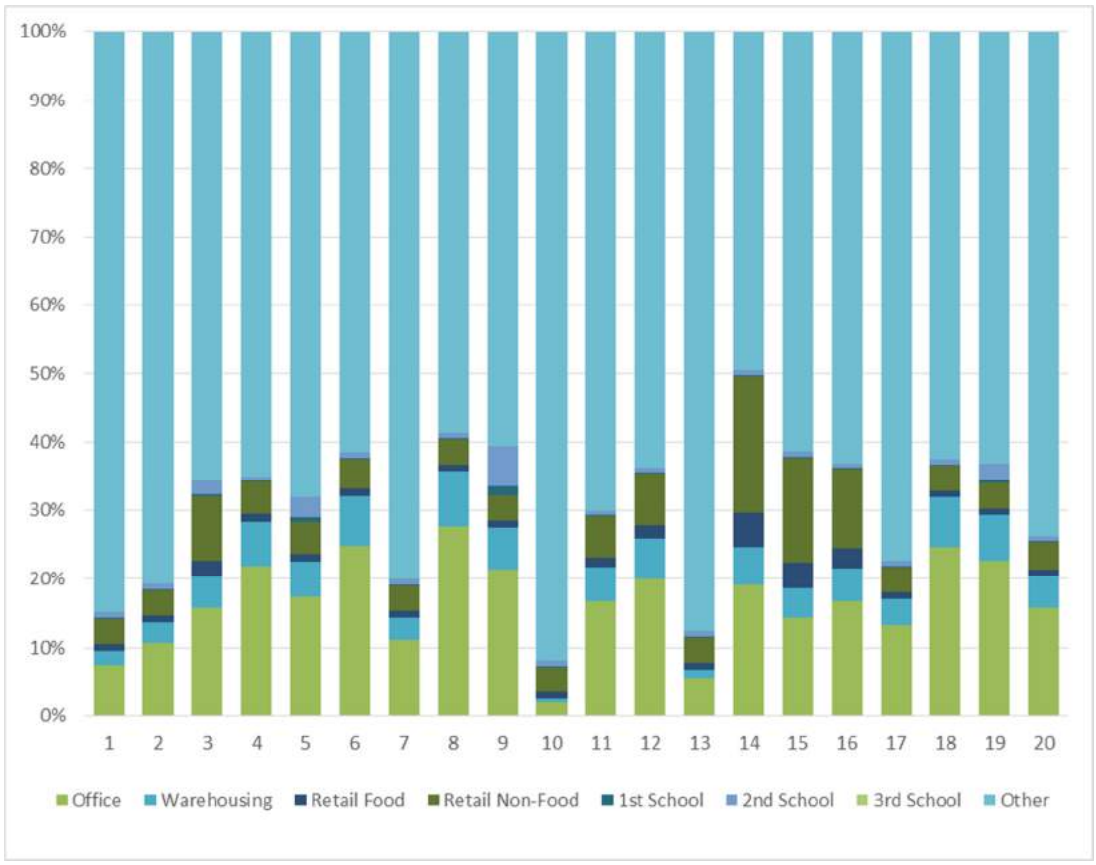


Figure 10. Residential Purpose Splits By Zone

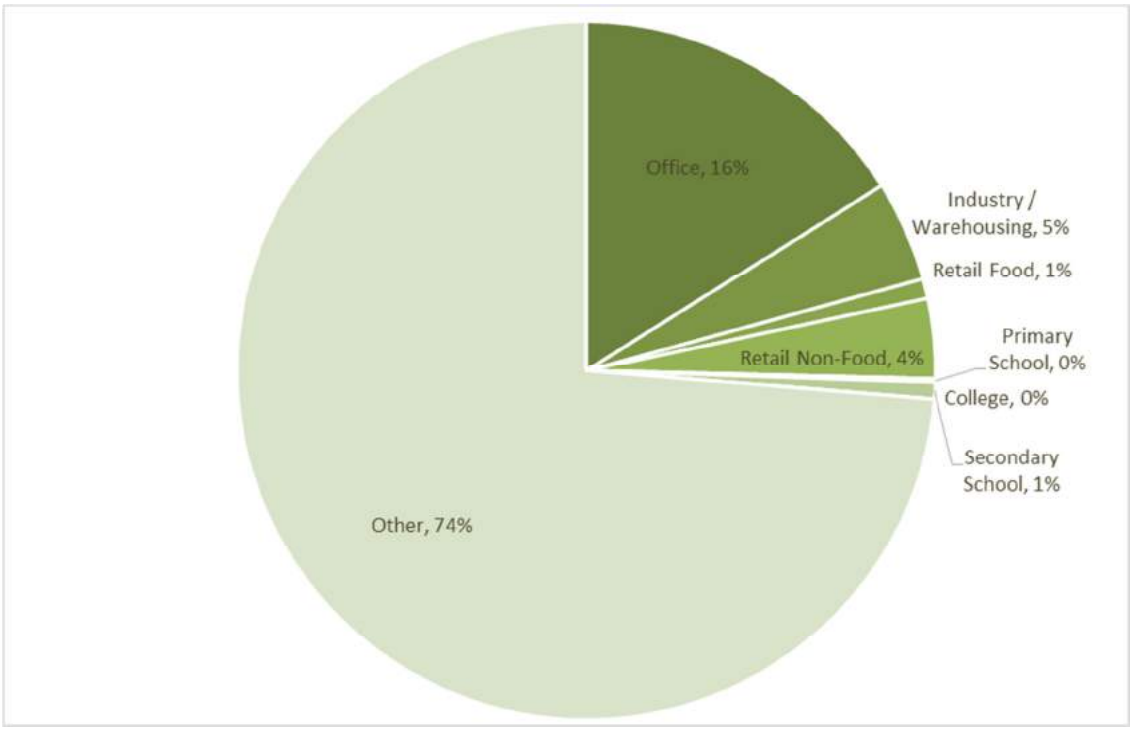


Figure 11. Average Residential Purpose Splits

3.7 Vehicle Splits

3.7.1 The vehicle type splits were calculated using the following process;

- The split between Petrol, Diesel and LPG cars was taken from Historic Trikala sales figures (2001-2013), factored according to European Car stock figures (from Eurostat) to account for recent diesel bias. This gave the following splits;
  - Petrol: 96.1%
  - Diesel: 3.6%
  - LPG: 0.3%
- Figures for Hybrid and Electric cars were calculated from Italian sales data from 2001 to 2013. These were taken from the International Council on Clean Transportation website[1]. This gives a share of 0.33% for Hybrids, which is then broken down to the different Hybrid types using UK fleet data. The registered data found that there were only six electric based vehicles sold within Trikala between the aforementioned period and has been rounded to zero.
- The split between cars and bikes, and between mopeds and motorbikes were taken from the European Commission Statistical Pocketbook 2012[2]. For Greece this gave the following;
  - 28% of vehicles are motorbikes or mopeds; and
  - 81% of these two-wheelers are motorbikes.

3.7.2 Combining these statistics gives the vehicle splits shown in Table 10 And Figure 12.

Table 10. Vehicle Splits – Highway

ID	VEHICLE TYPE	PERCENTAGE SPLIT
1	Petrol car inc Taxis	69.42%
2	Diesel car inc Taxis	2.58%
3	Petrol Full Hybrid Car	0.09%
4	Diesel Full Hybrid Car	0.06%
5	Petrol Plug-in Hybrid Car	0.09%
6	Electric Car	-
15	Moped	5.28%
16	Motorcycle	22.47%
17	LPG	0.01%

[1] http://www.theicct.org/sites/default/files/publications/EU_pocketbook_2014.pdf
[2] http://ec.europa.eu/transport/facts-fundings/statistics/doc/2012/pocketbook2012.pdf

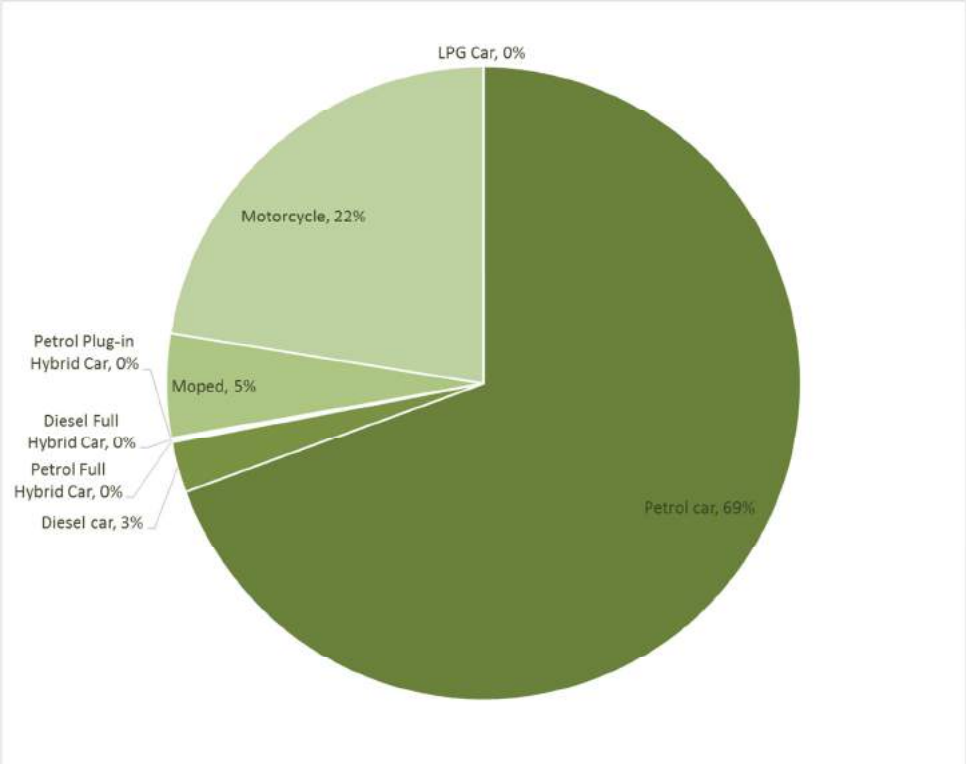


Figure 12. Highway Vehicle Splits

3.7.3 When compared to other survey data for similar sized cities, it can be observed that the percentage split of diesel cars in Trikala is noticeably small. This is caused by ban on diesel cars entering the major Greek cities of Athens and Thessaloniki up until 2012. Due to the ban, it was accepted that the diesel car industry had 'frozen', and that as 60% of the Greek population lived in one of the two cities, the demand for such vehicles was substantially reduced.

3.7.4 The split between different goods vehicles was taken from 2013 UK fleet split data as no Greek data could be sourced. The values used are shown in Table 11 and Figure 13.

Table 11. Goods Vehicle Splits

ID	VEHICLE TYPE	PERCENTAGE SPLIT
7	Petrol LGV	2.00%
8	Diesel LGV	84.00%
9	Rigid HGV	11.00%
10	Artic HGV	3.00%

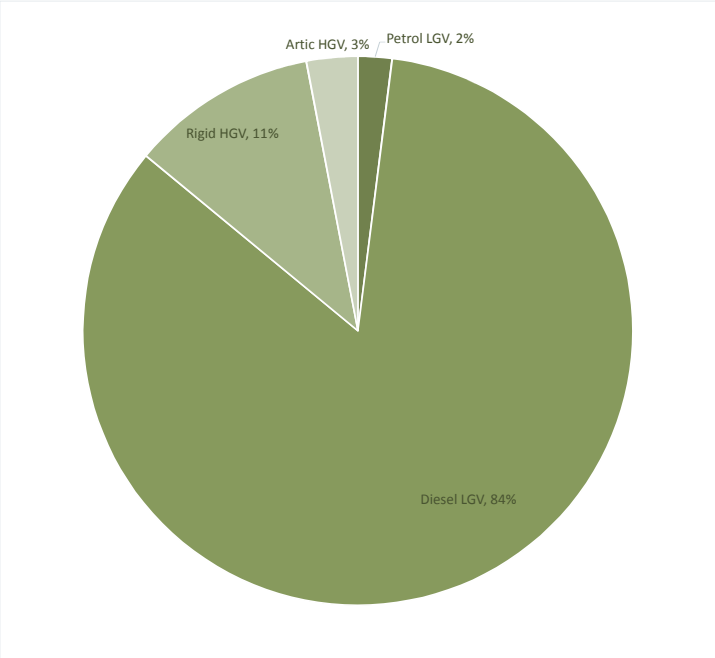


Figure 13. Goods Vehicle Splits

3.8 Parking

3.8.1 There are four formal car parksin Trikala, which are illustrated in Figure 14. Kanouta parking can be found within zone 1, Antoniou Square and Court House parking in zone 17, and the parking for the Hospital can be found in zone 11.

Figure 14. Parking in Trikala

3.8.2 The parking charge varies by zone and by hour, often with the first hour being noticibly more expensive than any subsequent hours. Details of the car parks are shown in Table 12.

3.8.3 **Note**: There is no modelling of parking capacity within the model. The cost of parking is an additional cost included when travelling to a zone with car parking.

3.8.4 Parking charges represent an average charge incurred by all trip terminating in the specific zone containing the car park.

3.8.5 To calculate the total cost of parking for each purpose it has been assumed that work-based purposes (Office & Industry/Warehousing) park for an eight hour working day. All other purposes (Retail, Education and Other types) are assumed to park for two hours.

3.8.6 In addition, the charges have been reduced by one third to reflect the availability of work place parking and free on-street parking. The resulting fares are shown in Table 13.

Table 12. Car Parks In Trikala

CAR PARK NAME	CAPACITY	PRICE (€/HR) – 1ST HR	PRICE (€/HR) – 2ND HR+	ZONE
Kanouta	40	1.60	0.80	1
Antoniou Square	94	2.00	0.80	17
Court House	132	1.40	0.70	17
Hospital	110	0.00	0.00	11

Table 13. Parking Charges By Zone

ZONE		WORK	OTHER
1	City Centre	€4.80	€1.60
11	General Hospital	€0.00	€0.00
17	Kentro	€4.56	€1.59

3.9 Internal & External Demand Splits

3.9.1 The external demand to and from the city is created by factoring the internal demand. This factor is taken from the Transport surveys. For Trikala the internal percentage is 98% of the total demand. This percentage is applied to highway, PT and goods demand as there is not sufficient information to get individual splits.

3.10 Public Transport Fares

3.10.1 The public transport fares are different for buses and trains in Trikala. Buses use a fare matrix, giving zone-zone fares. The zonal structure is based on the three route zones which cover the inner-city, adjacent and far settlements (zones A, B and C), each of which have different ticket prices. We have assumed all zones are in the Inner City zone A, with the exception of the outer ring of zones which has been classified as Far Settlements. The fare to external zones has been increased to attempt to increase rail demand.

3.10.2 The full fare matrix used in the model is shown in Table 15.

Table 14. Ticket Price Per Zone

ZONE	CATEGORY/ COLOUR	SINGLE
A (Inner City)	Green	€1,10
B (Adjacent Settlements)	Red	€1,50
C (Far Settlements)	Brown	€2,00

Table 15. Bus Fares By Area Type

AREA TYPE	CITY CENTRE	EDGE OF CITY CENTRE	SUBURBAN	RURAL/OUT SITE CITY	EXTERNAL
CITY CENTRE	€1.10	€1.10	€1.10	€2.00	€4.00
EDGE OF CITY CENTRE	€1.10	€1.10	€1.10	€2.00	€4.00
SUBURBAN	€1.10	€1.10	€1.10	€2.00	€4.00
RURAL/OUTSIDE CITY	€2.00	€2.00	€2.00	€2.00	€4.00
EXTERNAL	€4.00	€4.00	€4.00	€4.00	€4.00

3.10.3 The rail fares are distance based and use a price per km, which is multiplied by the distance travelled to get the fare. The cost per km was calculated using the fare from Trikala to Karditsa, which is €2.40 (taken from http://www.trainose.gr) and covers approximately 27km. This gives a cost per km of €0.09 per km.

4. CALIBRATION

4.1 Introduction

4.1.1 The model has been calibrated based on the Transport Survey data by looking at mode shares and average trip lengths. The quality of the public transport calibration is limited by the lack of data for this mode in the survey, which is felt to be under-represented. Only 44 trips were recorded as using public transport, with only three education trips. This compares to 1,012 records for highway trips. In addition, over 60% of the observed trips were "Other".

4.2 Mode Share

4.2.1 The Transport Survey has a car mode share of 95% across all zones and purposes. The model has a mode share of 94%.

4.2.2 Figure 15 shows the global modelled mode share. Figure 16 shows the mode share by purpose, with the work-based purposes having the highest car share.

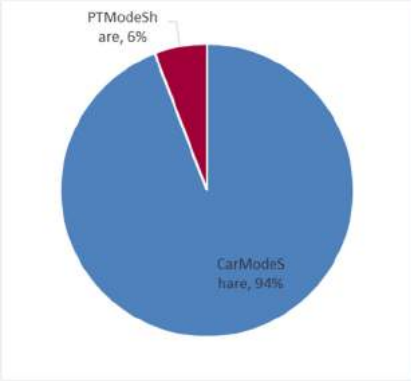


Figure 15. Global Mode Share

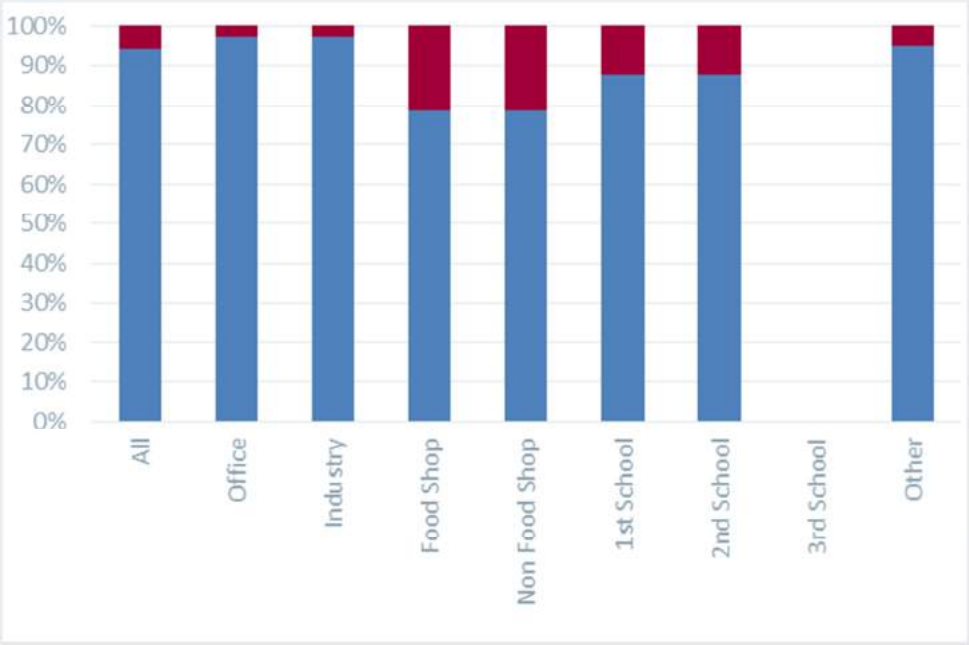


Figure 16. Mode Share by Purpose

4.3 Trip Length Distributions

4.3.1 The Transport Survey has average trip lengths for car and public transport of 2.5km and 2.6km respectively. These values are compared to the modelled average trip lengths of 2.5km and 2.1km, for car and public transport respectively.

4.3.2 The match of the highway to both average trip lengths and the overall trip length distribution is reasonably good. Figure 17 shows the relative and cumulative frequencies of the observed and model distributions. Figure 18 shows the average trip lengths by purpose, which also show a resoanable match, although there appears to be a number of very-short distance trips unaccounted for.

Figure 17. Highway Trip Length Distributions

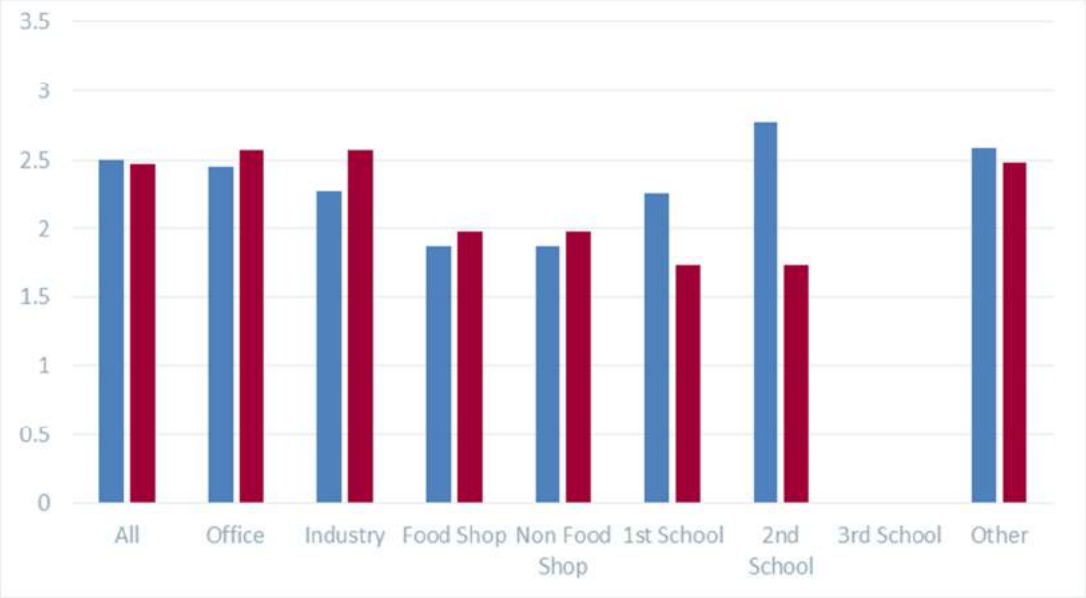


Figure 18. Highway Average Trip Lengths

4.3.3 The public transport distributions show a less good match, under-estimating the number of short distance trips. Figure 19 showing the distribution, and Figure 20 showing the average trip lengths by purpose, both illustrate this.

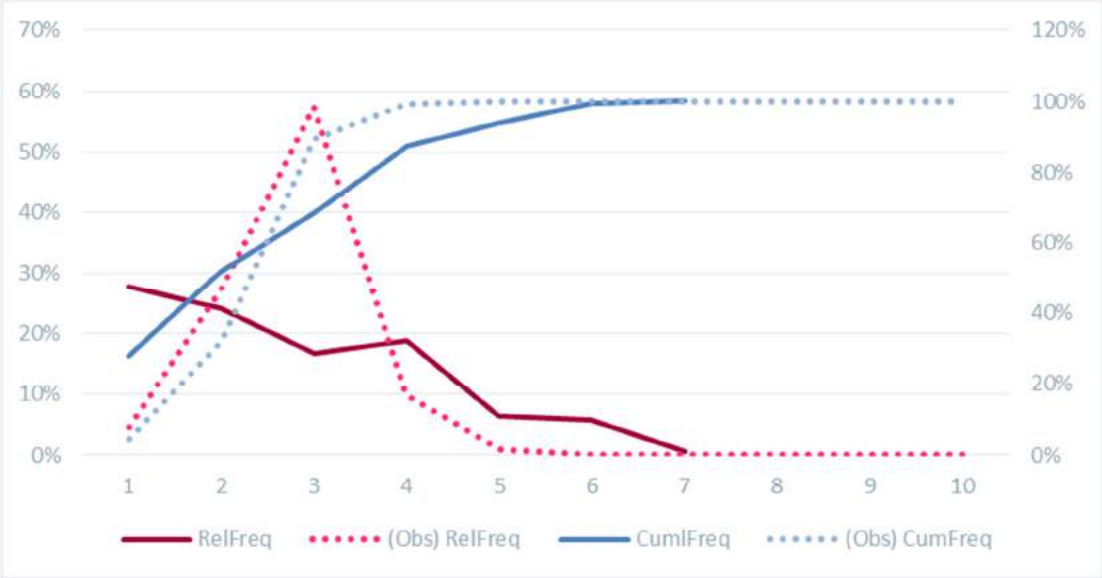


Figure 19. Public Transport Trip Length Distributions

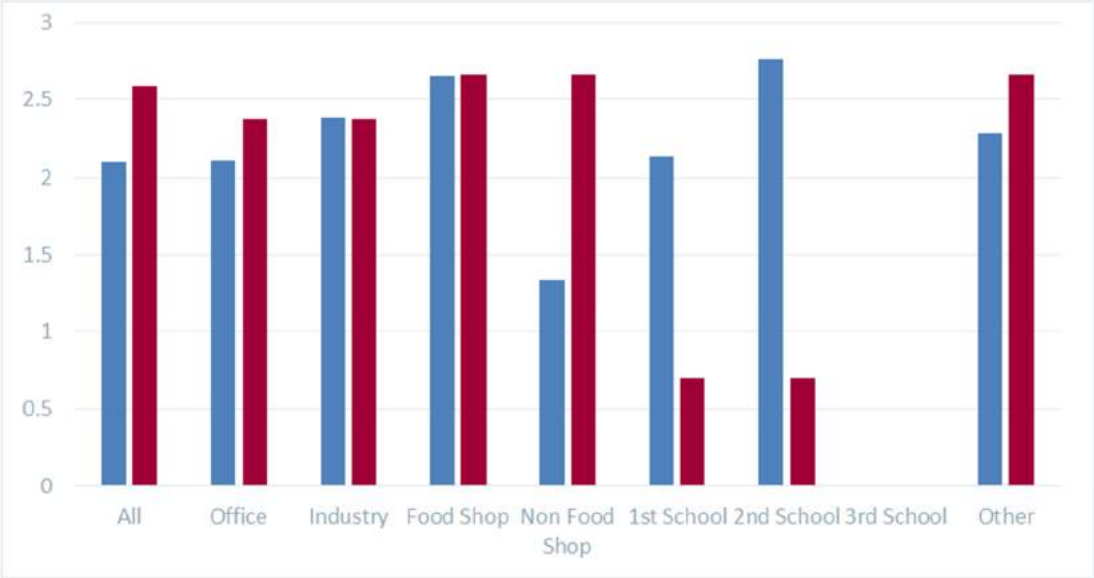


Figure 20. Public Transport Average Trip Lengths

4.3.4 It should be noted the calibration of the public transport trips is reliant upon on 44 observed trips, which is not a particulary large sample size. Although the data illustrates that there are no particulary anomalous results, the distinct lack of observed trips, especially for Educational purposes where there are only three data points, portrays a significant difference between the observed and modelled values. In practice however, it seems conceivable that Educational trip lengths could average between 2km and 2.5km, as modelled, but has not be.0en represented due to only three trips observed.

5. OUTPUTS

5.1 Introduction

5.1.1 This section looks at the outputs from the base year model run. It is split into three sections;

- **Demand Outputs** – by Origin, Destination, Vehicle Type and a comparison to actual vehicle numbers;
- **Energy Consumption Outputs** – Total energy, per person, per trip and split by vehicle type; and
- **Other Emissions Outputs** – Carbon Dioxide, Hydro Carbons, PM10s and Nitrous Oxide emissions.

5.2 Demand Outputs

5.2.1 This sections looks at the various demand outputs, checking they reflect the observed characteristics of the city. These include;

- Origin & Destination Plots;
- Demand by Purpose and Vehicle Type;
- Trip Rate checks;
- Comparison to actual vehicle figures; and
- Zone-zone demand matrices.

5.2.2 Figure 21 shows the Origins and Destinations of the demand by zone. The origins match the distribution of houses and flats, which is to be expected as all the trips are home-based.

5.2.3 Due to the high percentage of “Other” trips (74%) the destinations closely match the location of the “Other” floorspace types.

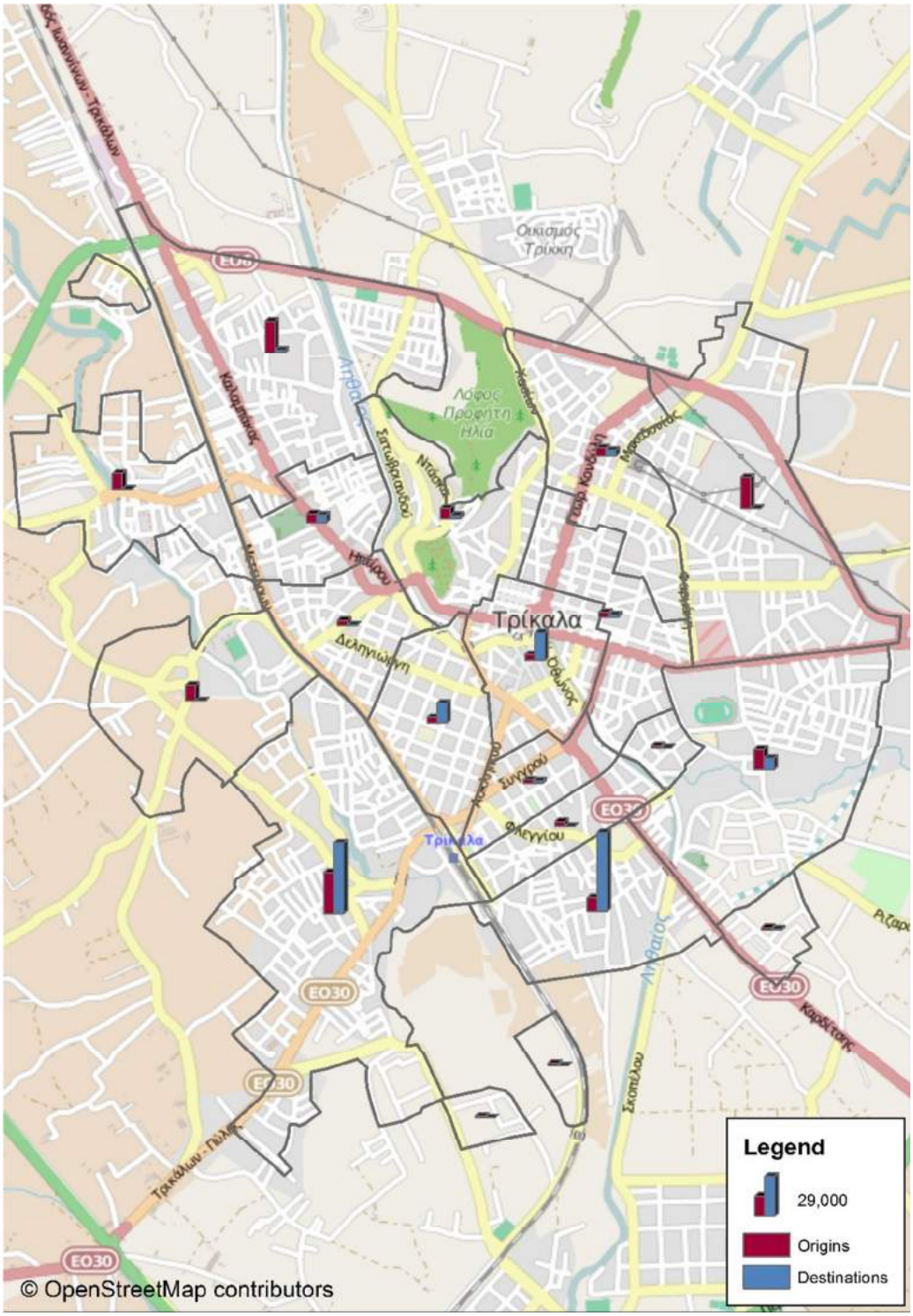


Figure 21. Origin & Destination Demand

5.2.4 Table 16 shows the demand split by purpose and mode (highway and PT). Highway based modes (including cars and motorbikes) make up most of the demand, particularly for work based purposes. The public transport mode share is highest for “Other” trips.

5.2.5 Table 16 also shows the average implied trip rate, per household, for each mode and purpose. Overall there are 2.81 two-way trips made each day per person. Figure 22 shows the purpose splits of the implied trip rates for each mode, highlighting the large number of “Other” trips on PT.

Table 16. Demand and Trip Rates By Purpose

PURPOSE	HIGHWAY DEMAND	PT DEMAND	HY TRIP RATE	PT TRIP RATE	TOTAL TRIP RATE
Commute - Office	33,048	1,903	0.53	0.031	0.56
Commute - Industrial/Warehousing	10,127	36	0.16	0.001	0.16
Retail - Food	2,280	123	0.04	0.002	0.04
Retail - Non Food	8,987	726	0.14	0.012	0.16
Education - Primary	432	10	0.01	0.000	0.01
Education - Secondary	2,021	45	0.03	0.001	0.03
Education - College	-	-	-	-	-
Other	109,001	6,156	1.75	0.099	1.85
Total	**165,897**	**8,998**	**2.67**	**0.145**	**2.81**
Mode Share	95%	5%			

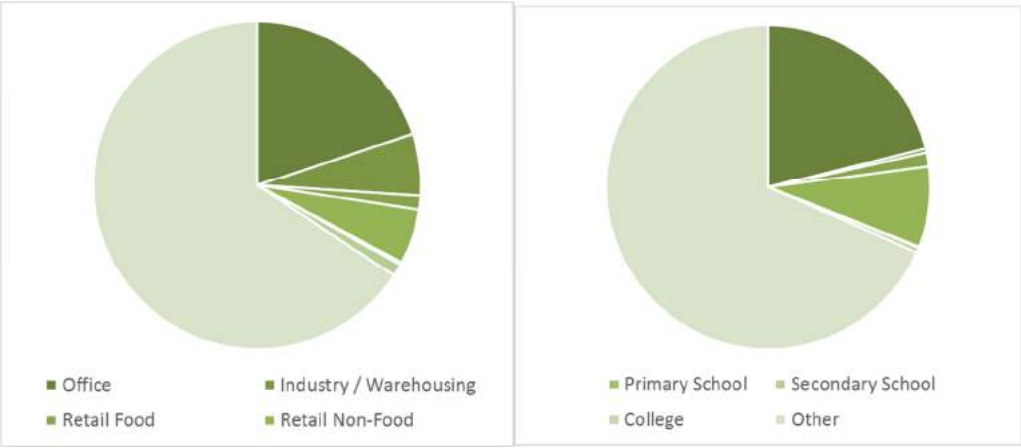


Figure 22. Highway & PT Trip Rates By Purpose

5.2.6 Table 17 shows the demand split into Vehicle Types and total vehicle kilometres. For the Private vehicles and Goods vehicles this reflects the Vehicle Splits input to the model. Public transport demand makes up 6% of the total demand, but less than 1% of vehicles.

5.2.7 Figure 23 shows the vehicle type splits graphically.

Table 17. Demand By Vehicle Type

VEHICLE TYPE	PERSON DEMAND	VEHICLE DEMAND	% PERSON	% VEHICLES	VEHICLE KMS
Petrol car	115,167	79,599	65%	61%	242,543
Petrol Full Hybrid Car	148	102	0%	0%	311
Petrol Plug-in Hybrid Car	148	102	0%	0%	311
Diesel car	4,282	2,959	2%	2%	9,018
Diesel Full Hybrid Car	98	68	0%	0%	206
Electric Car	-	-	0%	0%	-
LPG Car	10	7	0%	0%	21
Moped	8,761	8,761	5%	7%	26,765
Motorcycle	37,284	37,284	21%	29%	113,904
Petrol LGV	28	21	0%	0%	42
Diesel LGV	1,163	889	1%	1%	1,778
Rigid HGV	152	152	0%	0%	305
Artic HGV	42	42	0%	0%	83
Buses	10,798	478	6%	0%	-
Diesel Train	11	12	0%	0%	-
Total	**178,091**	**130,476**	**100%**	**100%**	**395,287**

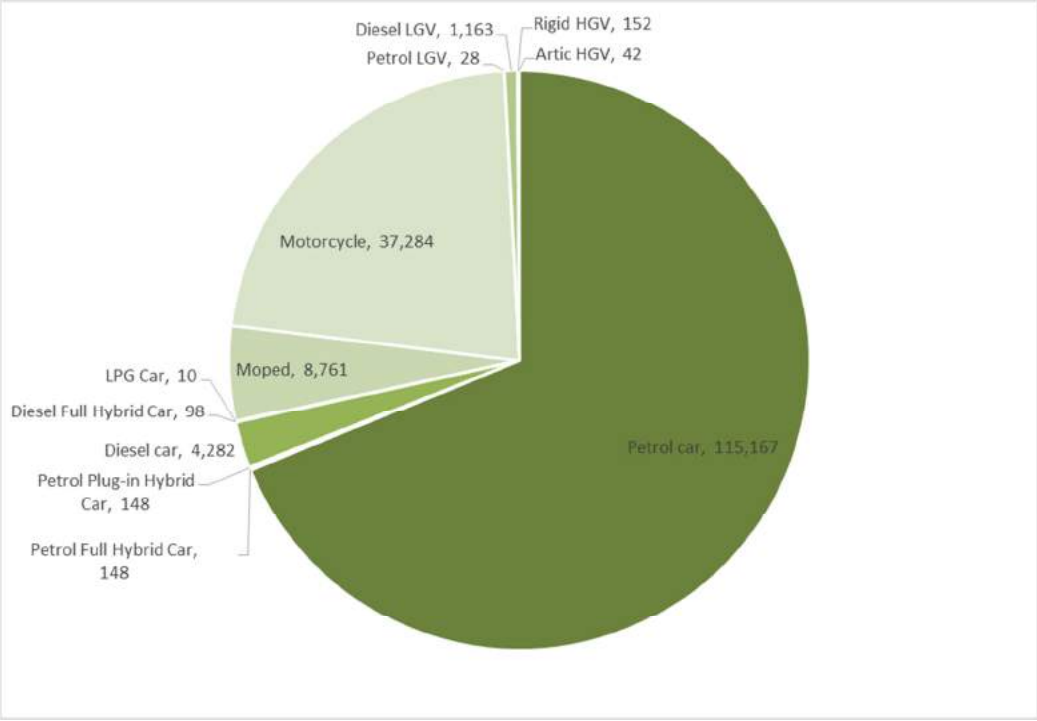


Figure 23. Demand By Vehicle Type

5.2.8 Table 18 provides a comparison between the modelled vehicles and actual fleet figures for Trikala. The actual figures were taken from ACAP Stock figures for 2010, and give values for cars, motorbike/mopeds and goods vehicles.

5.2.9 Overall, the match is poor, with the model underestimating both the car and goods vehicle types. Figure 24 shows the comparison graphically.

5.2.10 It is important to note that the number of modelled goods vehicles are directly related to the amount of Retail and Industry floorspace modelled – a small land use value for these purposes would result in a low flow demand. As such, drawing a comparision between Trikala and Evora, it can be seen that Evora has approximately 14 times more Retail and Indurstrial floorspace (1,550,000 sqm) than Trikala (112,00 sqm).

5.2.11 However, even in Evora the total number of Goods vehicles modelled is only around 1,500 (making a total of 6,500 journeys). Applying the factor of 14 to Trikala would result in around 3,500 goods vehicles, which is still some way short of the 21,500 observed figure.

Table 18. Modelled and Actual Vehicle Comparison

VEHICLE TYPE	ACAP STOCK (2010)	MODELLED	DIFFERENCE
Population	62,154	62,154	
Cars	40,829	31,035	-9,794
Motorbikes/Mopeds	15,760	17,251	1,491
Goods	21,543	245	-21,298
Total Vehicles	**78,132**	**48,532**	**-29,600**
Cars per person	0.66	0.50	
Bikes per person	0.25	0.28	

Figure 24. Comparison of Vehicle Totals with Actuals

5.2.12 Figure 25 to Figure 27 show the zone-zone movements for Private Vehicles (Cars and motorbikes), Public Transport and Goods Vehicles.

5.2.13 The Private Vehicles demand is focused on zones 11 and 12 as discussed previously. The PT demand also has a large proportion of demand going to zone 1 which reflects the relative accessibility of that zone via public transport. The goods vehicle demand is focused around large areas of industrial and retail floorspace.

All Purposes	1 City Centre	2 Alexandra	17 Kentro	20 Siggrou	9 Alonia Baras	10 Spartis	15 Archimidi	16 Dim Ntai	18 Varousi	3 Pirgos	4 Amygdalies	5 Papamanou	6 Pirgetos	7 Nekrotafio Trikalon	8 Keramaria	11 General Hospital	12 Agia Moni Gardikaki Ampelakia	13 Patmou	14 Flamouliou	19 Ethniko Stadium	21 External	Total	Origin Splits
1 City Centre	148	266	17	17	56	2	0	2	33	0	17	0	0	65	0	2180	994	9	0	142	40	3988	2%
2 Alexandra	158	717	21	27	53	3	0	3	32	0	19	0	0	70	0	1051	1711	10	0	75	40	3989	2%
17 Kentro	240	245	31	31	65	3	0	3	43	0	18	0	0	63	0	1986	947	15	0	205	40	3934	2%
20 Siggrou	146	188	20	34	38	2	0	2	22	0	11	0	0	37	0	1023	754	11	0	77	24	2390	1%
9 Alonia Baras	564	515	70	67	495	6	0	6	157	0	55	0	0	134	0	1950	1155	30	0	384	57	5644	3%
10 Spartis	13	20	2	3	12	0	0	0	3	0	1	0	0	4	0	1138	137	1	0	48	14	1397	1%
15 Archimidi	186	172	26	36	48	2	0	2	27	0	19	0	0	61	0	1878	503	16	0	245	33	3256	2%
16 Dim Ntai	222	559	29	24	57	6	0	6	48	0	51	0	0	262	0	830	1043	15	0	173	34	3358	2%
18 Varousi	738	1158	95	69	196	12	0	12	194	0	73	0	0	273	0	2316	1449	53	0	398	72	7108	4%
3 Pirgos	793	1276	98	80	304	11	0	11	141	0	241	0	0	868	0	2701	3706	38	0	428	109	10804	7%
4 Amygdalies	2188	2461	273	174	462	29	0	29	321	0	696	0	0	1180	0	5414	7054	105	0	764	215	21366	13%
5 Papamanou	124	81	18	26	66	2	0	2	21	0	9	0	0	31	0	1056	249	13	0	33	18	1746	1%
6 Pirgetos	1140	1238	155	117	219	21	0	21	178	0	157	0	0	480	0	1733	4789	57	0	378	109	10789	6%
7 Nekrotafio Trikalon	295	1009	35	28	84	6	0	6	56	0	60	0	0	358	0	1419	2669	13	0	109	63	6209	4%
8 Keramaria	2806	1455	375	276	741	29	0	29	464	0	227	0	0	535	0	7827	4603	186	0	1897	218	21668	13%
11 General Hospital	651	331	92	117	157	8	0	8	97	0	39	0	0	123	0	6751	654	85	0	409	97	9619	6%
12 Agia Moni Gardikaki Ampelakia	2309	2081	324	384	488	32	0	32	303	0	201	0	0	704	0	4814	16358	111	0	841	295	29278	18%
13 Patmou	49	32	7	9	22	1	0	1	8	0	3	0	0	10	0	1716	134	11	0	51	21	2072	1%
14 Flamouliou	97	63	14	14	22	1	0	1	12	0	9	0	0	30	0	599	167	12	0	154	12	1207	1%
19 Ethniko Stadium	1445	613	201	202	601	17	0	17	247	0	82	0	0	282	0	8075	1263	103	0	1314	147	14609	9%
21 External	146	148	19	18	43	2	0	2	25	0	20	0	0	57	0	576	513	9	0	83	0	1660	1%
Total	14456	14627	1921	1751	4228	194	0	194	2432	0	2007	0	0	5626	0	57033	50851	904	0	8208	1658	166091	
Destination Splits	9%	9%	1%	1%	3%	0%	0%	0%	1%	0%	1%	0%	0%	3%	0%	34%	31%	1%	0%	5%	1%		

Figure 25. Highway Demand

All Purposes	1 City Centre	2 Alexandra	17 Kentro	20 Siggrou	9 Alonia Baras	10 Spartis	15 Archimidi	16 Dim Ntai	18 Varousi	3 Pirgos	4 Amygdalies	5 Papamanou	6 Pirgetos	7 Nekrotafio Trikalon	8 Keramaria	11 General Hospital	12 Agia Moni Gardikaki Ampelakia	13 Patmou	14 Flamouliou	19 Ethniko Stadium	21 External	Total	Origin Splits
1 City Centre	150	19	4	0	1	0	0	0	1	0	2	0	0	4	0	62	92	0	0	7	3	344	4%
2 Alexandra	100	15	1	0	1	0	0	0	0	0	1	0	0	1	0	35	68	0	0	3	2	228	3%
17 Kentro	169	5	7	0	2	0	0	0	0	0	2	0	0	1	0	21	23	0	0	9	2	243	3%
20 Siggrou	41	4	1	0	1	0	0	0	0	0	0	0	0	1	0	33	6	0	0	2	1	90	1%
9 Alonia Baras	297	8	14	1	11	0	0	0	1	0	5	0	0	3	0	37	40	0	0	7	4	429	5%
10 Spartis	23	1	1	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0	2	0	37	0%
15 Archimidi	43	6	1	0	1	0	0	0	0	0	2	0	0	3	0	44	8	0	0	8	1	119	1%
16 Dim Ntai	80	12	1	0	1	0	0	0	1	0	5	0	0	9	0	16	50	0	0	8	2	185	2%
18 Varousi	315	21	5	0	2	0	0	0	3	0	6	0	0	13	0	37	90	0	0	7	5	503	6%
3 Pirgos	484	17	6	1	6	0	0	0	4	0	18	0	0	38	0	79	82	0	0	26	8	769	9%
4 Amygdalies	1057	34	49	1	12	0	0	0	7	0	20	0	0	41	0	158	168	0	0	27	16	1591	18%
5 Papamanou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
6 Pirgetos	278	38	7	1	3	0	0	0	4	0	3	0	0	7	0	44	165	0	0	14	6	569	6%
7 Nekrotafio Trikalon	286	8	2	0	1	0	0	0	1	0	3	0	0	7	0	40	43	0	0	4	4	402	4%
8 Keramaria	846	31	50	2	5	0	0	0	3	0	6	0	0	12	0	134	140	0	0	27	13	1270	14%
11 General Hospital	114	11	4	2	2	0	0	0	1	0	2	0	0	4	0	75	14	0	0	8	2	238	3%
12 Agia Moni Gardikaki Ampelakia	612	90	15	2	9	0	0	0	5	0	11	0	0	22	0	74	369	0	0	51	13	1273	14%
13 Patmou	24	3	0	0	0	0	0	0	0	0	0	0	0	1	0	27	4	0	0	1	1	62	1%
14 Flamouliou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
19 Ethniko Stadium	357	13	24	1	7	0	0	0	2	0	2	0	0	5	0	54	56	0	0	29	6	556	6%
21 External	54	3	2	0	1	0	0	0	0	0	1	0	0	2	0	10	15	0	0	2	0	90	1%
Total	5329	341	194	12	65	0	0	2	34	0	89	0	0	173	0	984	1439	2	0	244	90	8998	
Destination Splits	59%	4%	2%	0%	1%	0%	0%	0%	0%	0%	1%	0%	0%	2%	0%	11%	16%	0%	0%	3%	1%		

Figure 26. Public Transport Demand

All Purposes	1 City Centre	2 Alexandra	17 Kentro	20 Siggrou	9 Alonia Baras	10 Spartis	15 Archimidi	16 Dim Ntai	18 Varousi	3 Pirgos	4 Amygdalies	5 Papamanou	6 Pirgetos	7 Nekrotafio Trikalon	8 Keramaria	11 General Hospital	12 Agia Moni Gardikaki Ampelakia	13 Patmou	14 Flamouliou	19 Ethniko Stadium	21 External	Total	Origin Splits
1 City Centre	2	1	0	0	0	0	0	0	0	0	1	0	0	3	0	4	1	0	0	9	0	21	2%
2 Alexandra	1	7	0	0	0	0	0	0	0	0	2	0	0	6	0	10	8	0	0	8	0	43	3%
17 Kentro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
20 Siggrou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
9 Alonia Baras	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
10 Spartis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
15 Archimidi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
16 Dim Ntai	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
18 Varousi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
3 Pirgos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
4 Amygdalies	1	3	0	0	0	0	0	0	0	0	20	0	0	22	0	6	7	0	0	14	1	73	5%
5 Papamanou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
6 Pirgetos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
7 Nekrotafio Trikalon	3	5	0	0	0	0	0	0	0	0	11	0	0	75	0	7	12	1	0	19	1	135	10%
8 Keramaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
11 General Hospital	2	5	0	0	0	0	0	0	0	0	2	0	0	5	0	140	14	0	0	49	2	218	16%
12 Agia Moni Gardikaki Ampelakia	2	9	0	0	0	0	0	0	0	0	4	0	0	13	0	31	184	7	0	40	3	293	21%
13 Patmou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	21	0	11	0	39	3%
14 Flamouliou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
19 Ethniko Stadium	7	6	0	0	0	0	0	0	0	0	6	0	0	17	0	67	32	12	0	397	6	549	40%
21 External	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	3	0	0	4	0	14	1%
Total	17	35	0	0	0	0	0	0	0	0	45	0	0	143	0	268	268	42	0	553	14	1385	
Destination Splits	1%	3%	0%	0%	0%	0%	0%	0%	0%	0%	3%	0%	0%	10%	0%	19%	19%	3%	0%	40%	1%		

Figure 27. Goods Vehicle Demand

5.2.14 Table 19 shows the public transport boardings by bus and train. On average there is an average occupancy of 22.8 people per vehicle (**Note**: the train demand includes only demand going to/from Trikala and not demand passing through).

Table 19. PT Demand by Vehicle Type

ROUTE NO	BOARDINGS	DAILY SERVICES	AVERAGE OCCUPANCY
Buses	10,798	462	23.4
Trains	11	12	0.9
Total	**10,809**	**474**	**22.8**
PT Demand	8,998		
Average Boardings Per Journey	1.20		

5.2.15 It should be noted that the low average occupancy for rail is due to the high percentage of the external demand that are travelling via bus. This is related to the ease of access it provides compared to rail, which needs to be accessed by a bus routes for all zones except zone 2. In reality, there is probably a greater number of people walking to the rail station (as the city is relatively small), or being dropped off – both of which are not captured in this model.

5.3 Energy Outputs

5.3.1 This section covers the Energy Consumption/Usage within Trikala. This includes;

- Total Energy per person, trip and vehicle type;
- Energy by Origin zone; and
- Zone-zone Energy flows.

5.3.2 Table 20 presents a summary of the total energy used by transport within Trikala. The total value across all modes, vehicle types, purposes and zones is **934,855 MJ**, which is around 15MJ per person per day.

Table 20. Energy Usage Summary

NO	TOTAL	CARS	BIKES	GOODS	BUSES	TRAINS
Total Energy (MJ)	**934,855**	**625,389**	**230,646**	**11,960**	**62,150**	**4,711**
Population	62,154					
Energy Per Person (MJ)	15.0	10.1	3.7	0.2	1.0	0.1
Demand (Persons)	178,091	119,852	46,045	1,385	10,798	11
Energy Per Trip (MJ)	5.2	5.2	5.0	8.6	5.8	410.0
Trips Per Person	2.9	1.9	0.7	0.0	0.2	0.0
Actual Vehicles	54,132	31,036	22,729	249	106	12
Energy Per Vehicle (MJ)	17.3	20.2	10.1	48.1	585.1	392.5
Vehicles Per Person	0.87	0.50	0.37	0.00	0.00	0.000

Note 1: Energy per Person for Goods demand isn't really meaningful as the demand is not based on residential locations. An increase in population would not necessarily lead to an increase in goods demand in the same way it would with car demand.

5.3.3 When compared to the same values from the other cities, Table 20 shows that Trikala has the smallest energy output. It is expected that a number of factors contribute to this outcome, the smaller size of the city and thus shorter trips lengths, and the lack of major external attractions within a close proximity consequently reducing the number of external trips, are two significant ones.

5.3.4 Table 21 shows the Energy figures split into Vehicles Types. Surprisingly Bus demand use the most energy compared to the number of vehicles – consuming 7% of the total energy from less than 1% of the vehicles.

5.3.5 Figure 28 shows the Energy Usage split by Vehicle Type.

Table 21. Energy Consumption (MJ) by Vehicle Type

VEHICLE TYPE	TOTAL ENERGY	% ENERGY	VEHICLES	ENERGY PER VEHICLE
Petrol car	604,520	65%	29,822	20
Petrol Full Hybrid Car	343	0%	38	9
Petrol Plug-in Hybrid Car	330	0%	38	9
Diesel car	19,932	2%	1,109	18
Diesel Full Hybrid Car	202	0%	25	8
Electric Car	-	-	-	-
LPG Car	62	0%	3	24
Moped	24,052	3%	8,761	3
Motorcycle	206,594	22%	13,968	15
Petrol LGV	174	0%	8	22
Diesel LGV	6,597	1%	198	33
Rigid HGV	3,556	0%	34	105
Artic HGV	1,633	0%	9	177
Buses	62,150	7%	106	585
Diesel Train	4,711	1%	12	393
Total	**934,855**	**100%**	**54,132**	**17**
Cars	625,389	67%	31,035	20
Bikes	230,646	25%	22,729	10
Goods	11,960	1%	249	48
Buses	62,150	7%	106	585
Trains	4,711	1%	12	393

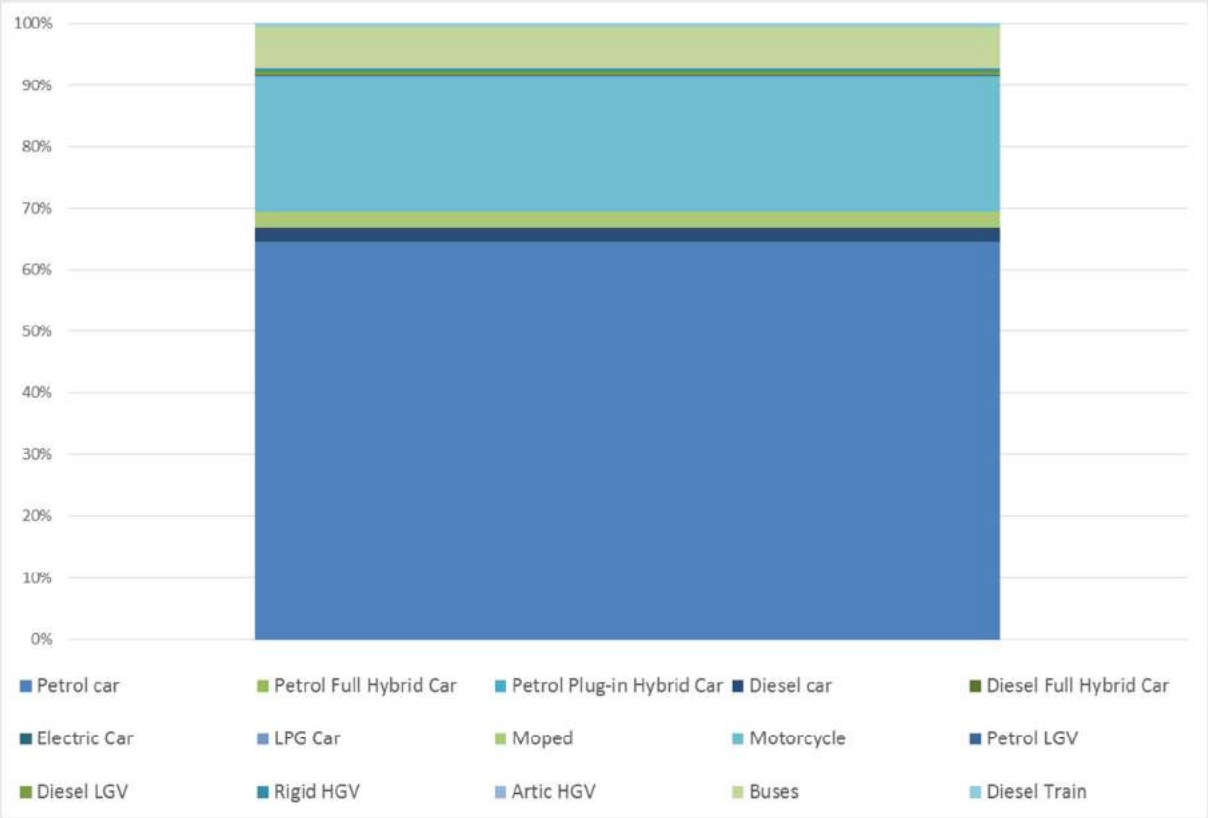


Figure 28. Energy Usage By Vehicle Type

5.3.6 Table 22 shows the Energy Usage split into zones, based on the residential origin of the trip. Figure 29 shows the total energy per zone and Figure 30 shows the energy per person. There are a number effects present here;

- Zones further out consume more energy due to the distance they have to travel, primarily to central zones. Looking at the total energy per zone at an Area Type level, there is generally an increase in these values as you move towards the suburbs of the city.
- Zones with a low population consume little energy – for example zones 5, 10, 13 and 14. The zones with a higher population, such as zones 4 or 12, are often towards the suburbs of the city, and thus consume a significant amount of energy, mainly due to the longer distances they have to travel to an attraction.

Table 22. Energy Per Zone – Private Vehicles

NO	ZONE NAME	AREA TYPE	POP	DEMAND	ENERGY (MJ)	ENERGY/ PERSON	ENERGY /TRIP
1	City Centre	1	2,537	2,958	16,307	6.4	5.5
2	Alexandra	2	2,473	2,989	12,657	5.1	4.2
17	Kentro	2	2,599	2,975	15,896	6.1	5.3
20	Siggrou	2	1,378	1,823	7,249	5.3	4.0
9	Alonia Baras	3	3,434	4,428	29,192	8.5	6.6
10	Spartis	3	506	1,016	3,598	7.1	3.5
15	Archimidi	3	1,417	2,511	9,839	6.9	3.9
16	Dim Ntai	3	2,042	2,596	13,619	6.7	5.2
18	Varousi	3	2,860	5,587	33,102	11.6	5.9
3	Pirgos	4	3,491	8,326	64,760	18.6	7.8
4	Amygdalies	4	7,323	16,670	144,227	19.7	8.7
5	Papamanou	4	527	1,345	5,985	11.4	4.4
6	Pirgetos	4	4,031	8,485	62,041	15.4	7.3
7	Nekrotafio Trikalon	4	1,995	4,663	28,690	14.4	6.2
8	Keramaria	4	6,917	17,200	133,185	19.3	7.7
11	General Hospital	4	2,974	7,375	25,655	8.6	3.5
12	Agia Moni Gardikaki Ampelakia	4	9,422	22,748	111,284	11.8	4.9
13	Patmou	4	644	1,525	5,721	8.9	3.8
14	Flamouliou	4	364	952	5,037	13.8	5.3
19	Ethniko Stadium	4	5,222	11,422	65,278	12.5	5.7
21	External	5	-	1,288	62,711	-	48.7
	Total (inc External)			**128,882**	**856,035**	**-**	**6.6**
	Total (exl External)		**62,154**	**127,593**	**793,324**	**12.8**	**6.2**

Figure 29. Total Energy (MJ) Per Origin Zone

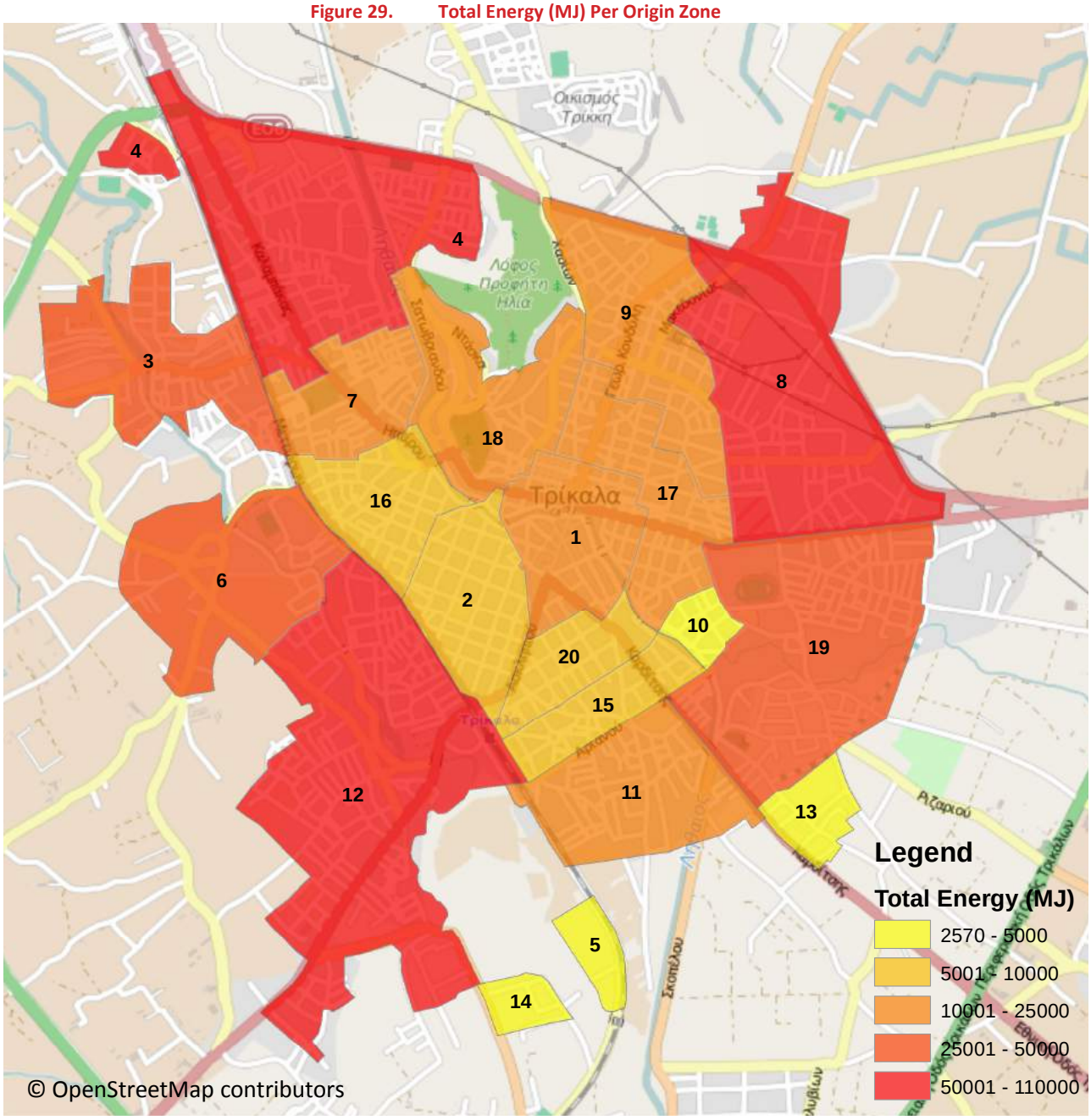
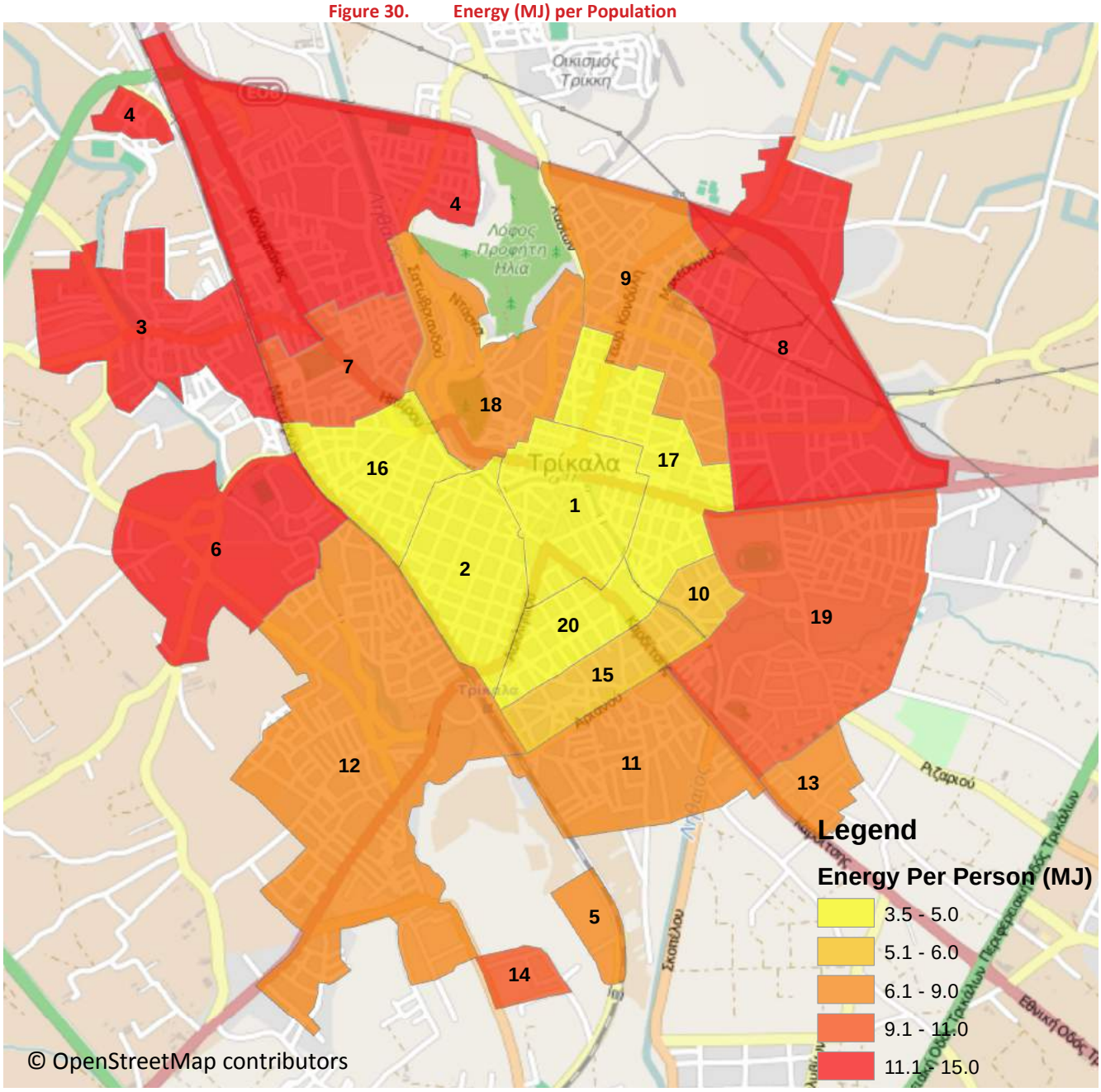


Figure 30. Energy (MJ) per Population



5.3.7 Table 23 to Table 25 show the zone-zone energy usage.

5.3.8 However, the Public Transport energy is calculated on the basis of the actual vehicles serving the routes, rather than the demand. They are then allocated based on the start and end zone of each service. Hence, the majority of the PT energy is to/from zone 1 which is where most routes start or end.

Table 23. Zonal Energy Usage – Private Vehicles

Private Vehicles	1 City Centre	2 Alexandra	17 Kentro	20 Siggrou	9 Alonia Baras	10 Spartis	15 Archimidi	16 Dim Ntai	18 Varousi	3 Pirgos	4 Amygdalies	5 Papamanou	6 Pirgetos	7 Nekrotafio Trikalon	8 Keramaria	11 General Hospital	12 Agia Moni Gardikaki Ampelakia	13 Patmou	14 Flamouliou	19 Ethniko Stadium	21 External	Total	Origin Splits
1 City Centre	279	940	37	59	156	-	-	6	80	-	96	-	-	219	-	7,913	4,488	44	-	535	1,455	16,307	8%
2 Alexandra	691	1,103	98	73	261	-	-	8	113	-	110	-	-	255	-	3,405	4,566	54	-	449	1,472	12,657	6%
17 Kentro	522	942	62	106	271	-	-	13	158	-	128	-	-	306	-	6,973	4,153	72	-	723	1,468	15,896	8%
20 Siggrou	501	428	68	57	202	-	-	9	112	-	81	-	-	195	-	2,334	1,964	46	-	357	896	7,249	3%
9 Alonia Baras	1,649	2,315	309	373	925	-	-	32	512	-	334	-	-	751	-	10,341	7,331	221	-	1,909	2,191	29,192	14%
10 Spartis	695	1,260	125	112	279	-	-	10	153	-	240	-	-	598	-	3,703	4,104	86	-	973	1,283	13,619	6%
15 Archimidi	1,815	3,377	352	355	636	-	-	39	440	-	438	-	-	1,041	-	10,874	8,469	332	-	2,158	2,775	33,102	16%
16 Dim Ntai	1,815	3,377	352	355	636	-	-	39	440	-	438	-	-	1,041	-	10,874	8,469	332	-	2,158	2,775	33,102	16%
18 Varousi	1,815	3,377	352	355	636	-	-	39	440	-	438	-	-	1,041	-	10,874	8,469	332	-	2,158	2,775	33,102	16%
3 Pirgos	4,323	5,624	685	561	2,125	-	-	52	814	-	1,030	-	-	2,562	-	17,790	21,238	361	-	3,466	4,128	64,760	31%
4 Amygdalies	13,082	13,123	2,056	1,414	2,912	-	-	159	2,069	-	1,892	-	-	4,316	-	39,522	47,484	1,078	-	6,816	8,305	144,227	68%
5 Papamanou	826	320	113	104	503	-	-	10	138	-	77	-	-	197	-	1,869	861	51	-	260	659	5,985	3%
6 Pirgetos	8,482	4,827	1,106	732	1,647	-	-	79	1,081	-	900	-	-	2,094	-	10,269	22,911	491	-	3,215	4,205	62,041	29%
7 Nekrotafio Trikalon	1,009	2,988	171	152	446	-	-	15	215	-	201	-	-	560	-	8,086	11,746	103	-	703	2,294	28,690	14%
8 Keramaria	13,584	9,374	1,779	1,742	2,779	-	-	215	2,439	-	1,721	-	-	4,049	-	44,928	31,517	1,232	-	9,228	8,599	133,185	63%
11 General Hospital	3,151	1,378	429	363	1,034	-	-	49	599	-	358	-	-	927	-	9,236	2,542	227	-	1,722	3,640	25,655	12%
12 Agia Moni Gardikaki Ampelakia	11,175	5,403	1,514	1,115	2,974	-	-	138	1,833	-	1,300	-	-	3,214	-	13,938	27,610	533	-	4,674	8,411	83,832	40%
13 Patmou	253	158	32	35	144	-	-	4	48	-	31	-	-	78	-	3,360	617	15	-	202	743	5,721	3%
14 Flamouliou	721	294	99	68	149	-	-	8	106	-	86	-	-	209	-	1,461	710	32	-	626	467	5,037	2%
19 Ethniko Stadium	6,234	3,825	805	1,043	3,052	-	-	108	1,450	-	760	-	-	1,987	-	28,384	7,895	465	-	3,584	5,683	65,278	31%
21 External	6,583	5,730	888	800	1,830	-	-	90	1,120	-	870	-	-	2,461	-	19,993	18,439	399	-	3,508	-	62,711	30%
Total	79,205	70,163	11,431	9,977	23,598	-	-	1,122	14,361	-	11,527	-	-	28,101	-	266,129	245,581	6,506	-	49,424	64,224	881,349	
Destination Splits	9%	8%	1%	1%	3%	0%	0%	0%	2%	0%	1%	0%	0%	3%	0%	30%	28%	1%	0%	6%	7%		

Table 24. Zonal Energy Usage – Goods Vehicles

Goods Vehicles	1 City Centre	2 Alexandra	17 Kentro	20 Siggrou	9 Alonia Baras	10 Spartis	15 Archimidi	16 Dim Ntai	18 Varousi	3 Pirgos	4 Amygdalies	5 Papamanou	6 Pirgetos	7 Nekrotafio Trikalon	8 Keramaria	11 General Hospital	12 Agia Moni Gardikaki Ampelakia	13 Patmou	14 Flamouliou	19 Ethniko Stadium	21 External	Total	Origin Splits
1 City Centre	6	6	-	-	-	-	-	-	-	-	9	-	-	22	-	33	16	-	-	72	18	182	2%
2 Alexandra	7	26	-	-	-	-	-	-	-	-	18	-	-	43	-	76	54	-	-	99	35	359	3%
17 Kentro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
20 Siggrou	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
9 Alonia Baras	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
10 Spartis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
15 Archimidi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
16 Dim Ntai	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
18 Varousi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
3 Pirgos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
4 Amygdalies	16	30	-	-	-	-	-	-	-	-	106	-	-	153	-	112	110	7	-	245	62	841	7%
5 Papamanou	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
6 Pirgetos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
7 Nekrotafio Trikalon	18	33	-	-	-	-	-	-	-	-	71	-	-	234	-	99	138	11	-	251	113	968	8%
8 Keramaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
11 General Hospital	17	37	-	-	-	-	-	-	-	-	33	-	-	65	-	462	116	-	-	407	181	1,318	11%
12 Agia Moni Gardikaki Ampelakia	20	63	-	-	-	-	-	-	-	-	62	-	-	154	-	276	1,064	94	-	605	258	2,597	22%
13 Patmou	-	-	-	-	-	-	-	-	-	-	2	-	-	5	-	-	78	60	-	94	35	273	2%
14 Flamouliou	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
19 Ethniko Stadium	53	70	-	-	-	-	-	-	-	-	99	-	-	221	-	574	486	117	-	2,179	468	4,266	36%
21 External	14	29	-	-	-	-	-	-	-	-	37	-	-	119	-	220	234	37	-	466	-	1,156	10%
Total	150	295	-	-	-	-	-	-	-	-	437	-	-	1,018	-	1,851	2,297	326	-	4,417	1,169	11,960	
Destination Splits	1%	2%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	9%	0%	15%	19%	3%	0%	37%	10%		

Table 25. Zonal Energy Usage – Public Transport

All PT	1 City Centre	2 Alexandra	17 Kentro	20 Siggrou	9 Alonia Baras	10 Spartis	15 Archimidi	16 Dim Ntai	18 Varousi	3 Pirgos	4 Amygdalies	5 Papamanou	6 Pirgetos	7 Nekrotafio Trikalon	8 Keramaria	11 General Hospital	12 Agia Moni Gardikaki Ampelakia	13 Patmou	14 Flamouliou	19 Ethniko Stadium	21 External	Total	Origin Splits
1 City Centre	-	-	-	-	-	-	-	-	-	1,234	2,376	-	-	-	-	-	353	-	-	-	27,112	31,075	46%
2 Alexandra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,355	2,355	4%
17 Kentro	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
20 Siggrou	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
9 Alonia Baras	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
10 Spartis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
15 Archimidi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
16 Dim Ntai	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
18 Varousi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
3 Pirgos	1,234	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,234	2%
4 Amygdalies	2,376	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,376	4%
5 Papamanou	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
6 Pirgetos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
7 Nekrotafio Trikalon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
8 Keramaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
11 General Hospital	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
12 Agia Moni Gardikaki Ampelakia	353	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	353	1%
13 Patmou	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
14 Flamouliou	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
19 Ethniko Stadium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
21 External	27,112	2,355	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29,467	44%
Total	31,075	2,355	-	-	-	-	-	-	-	1,234	2,376	-	-	-	-	-	353	-	-	-	29,467	66,860	
Destination Splits	46%	4%	0%	0%	0%	0%	0%	0%	0%	2%	4%	0%	0%	0%	0%	0%	1%	0%	0%	0%	44%		

5.3.9 Table 26 shows the energy usage for buses and trains within Trikala, including energy per passenger and per vehicle km.

Table 26. PT Energy Usage By Vehicle Type

ROUTE NO	TOTAL ENERGY	SERVICES	ROUTE LENGTH (KM)	VEHICLE KMS	ENERGY/ VEHKMS	ENERGY/ PASS
Buses	62,150	462	195.5	7,602	8.17	5.76
Train	4,711	12	21.5	258	18.26	428.23
Total	**66,860**	**474**	**217.0**	**7,860**	**8.51**	**6.19**

5.4 Emissions Outputs

5.4.1 This section of the report looks at other emissions calculated by the model. These include;

- Nitrous Oxides;
- Particulate Matter (PM10s);
- Hydro Carbons;
- Carbon Monoxide; and
- Carbon Dioxide.

5.4.2 Figure 28 shows the Carbon Dioxide Emissions split into Vehicle Type. These splits are very similar to the Energy Usage splits.

5.4.3 Figure 29 shows the Vehicle Type splits for the other Emissions types. It can be seen that the splits here are very different to the Carbon Dioxide splits, shown on the far right. Mopeds and Motorbikes are more responsible for Hydro-Carbons, PM10s and Carbon Monoxide.

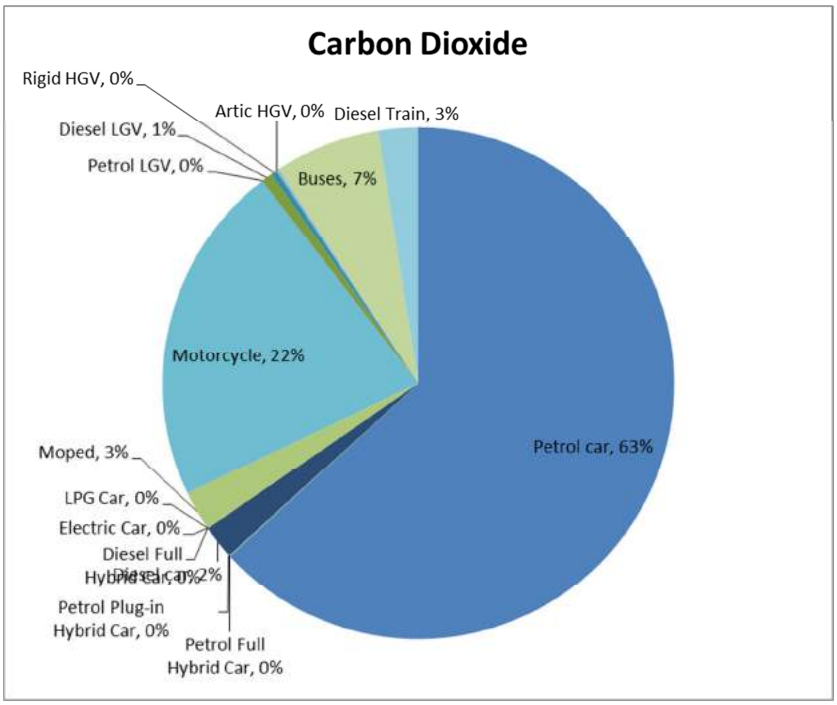


Figure 31. Carbon Dioxide Emissions By Vehicle Type

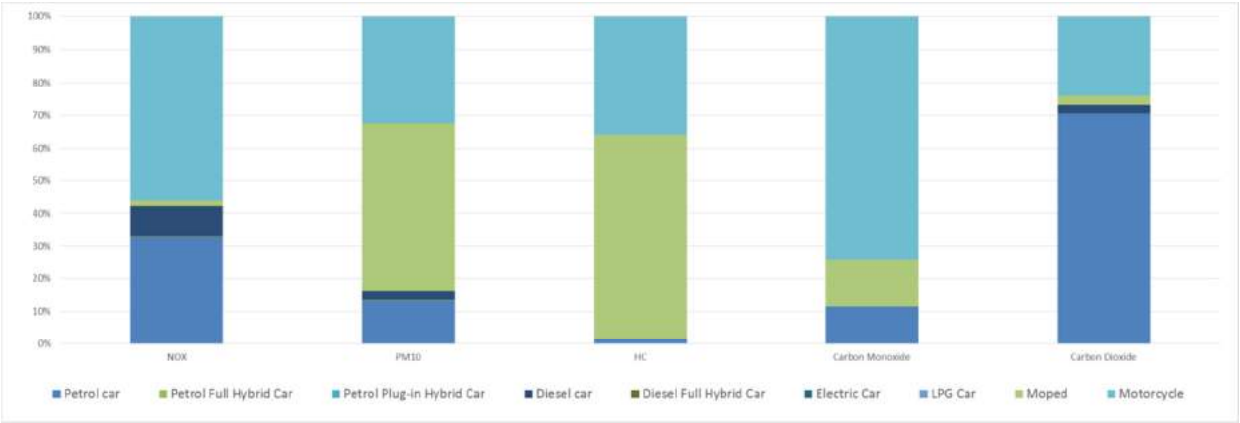


Figure 32. Emissions by Vehicle Type

Table 27. Emissions By Vehicle Type (Kg)

VEHICLE TYPE	NOX	PM10	HCS	CO	CO2
Petrol car	12.933	0.731	4.025	158.694	44,455.971
Petrol Full Hybrid Car	0.009	0.001	0.002	0.096	25.218
Petrol Plug-in Hybrid Car	0.005	-	0.002	0.091	24.236
Diesel car	3.539	0.143	0.196	0.442	1,503.426
Diesel Full Hybrid Car	0.047	0.002	0.002	0.004	15.261
Electric Car	-	-	-	-	-
LPG Car	0.005	-	0.001	0.002	3.890
Moped	0.712	2.780	172.600	195.732	1,768.791
Motorcycle	21.968	1.768	98.344	1,032.761	15,192.767
Petrol LGV	0.004	-	0.002	0.113	12.824
Diesel LGV	1.013	0.047	0.071	0.376	497.580
Rigid HGV	1.157	0.016	0.030	0.181	268.206
Artic HGV	0.541	0.007	0.012	0.051	123.176
Buses	21.692	0.268	0.574	2.134	4,687.887
Diesel Train	-	-	-	-	1,780.974
Total	**63.625**	**5.764**	**275.862**	**1,390.676**	**70,360.208**
Cars	16.537	0.878	4.229	159.330	46,028.003
Bikes	22.680	4.549	270.944	1,228.493	16,961.557
Goods	2.715	0.070	0.115	0.720	901.786
Buses	21.692	0.268	0.574	2.134	4,687.887
Trains	-	-	-	-	1,780.974

WP3 – Transport and Mobility Analysis

D.3.3. Transport Base Year Report Evora

October 2015

314164 (ENER/FP7/314164)

Project acronym:

InSMART

Project full title:

Integrative Smart City Planning

Coordination and support action (Coordinating Action)

FP7-ENERGY-SMARTICITIES-2012

Start date of project: 2013-12-01

Duration: 3 years

Deliverable D3.3

Transport Base Year Report Evora

Work Package 3. Transport and Mobility Analysis

October 2015

Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Executive Summary	
This report presents the results of the Baseline Scenario of the transport model that has been developed in the framework of the INSMART project for the city of Evora.	
Keywords	Transport scenarios




BASE YEAR REPORT - EVORA

INSMART – INTEGRATIVE SMART CITY PLANNING

BASE YEAR REPORT - EVORA

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1. INTRODUCTION

1.1 Project Overview

1.1.1 InSmart is a three year, European funded project which involves four European Cities working partnership towards a sustainable energy future. The primary objective of the project is to develop sustainable energy action plans for each partner city.

1.1.2 The four cities are Cesena;

- Cesena, Italy;
- Evora, Portugal;
- Nottingham, UK; and
- Trikala, Greece.

1.1.3 A mix of sustainable energy measures to improve the energy efficiency of each city will be identified through the use of a variety of tools and approaches and covering a wide range of sectors from the residential and transport sectors to street lighting and waste collection.

1.1.4 SYSTRA's role within the project is to identify, test and report on a series of land use and transport based strategies aimed at reducing the transport-related energy usage and carbon generation of each city.

1.1.5 The initial task is to calculate the current energy usage and carbon emissions generated by each city. The impact of the forecast strategies can then be obtained by comparison with the base figures.

1.2 Evora

1.2.1 This report covers the city of Evora in the Portuguese region of Alentejo.

1.2.2 The city has been split into 21 zones, as shown in Figure 1. Figure 2 shows a zoomed in map of the zoning system covering the city centre area. In addition the model has a 22nd zone covering the area external to the 21 internal zones – allowing for travel to and from the city.

1.2.3 The city has also been split into 5 Area Types representing different areas of the city. These are

- City Centre;
- Edge of City Centre;
- Sub-Urban areas;
- Rural/Outside City; and
- External.

1.2.4 Some inputs, such as vehicle speeds, are at this more aggregate level of detail. The Area Type allocation for the internal zones is shown in Figure 3.

1.3 Report Structure

1.3.1 The report is split into four sections

- Executive Summary/Conclusions – the key aspects of the Base Year model outputs;
- Inputs – covering all the city-specific inputs;
- Calibration – details of model calibration to observed mode share and trip length information; and
- Outputs – details of demand movements, energy consumption and emissions.

Figure 1. Evora Zoning System

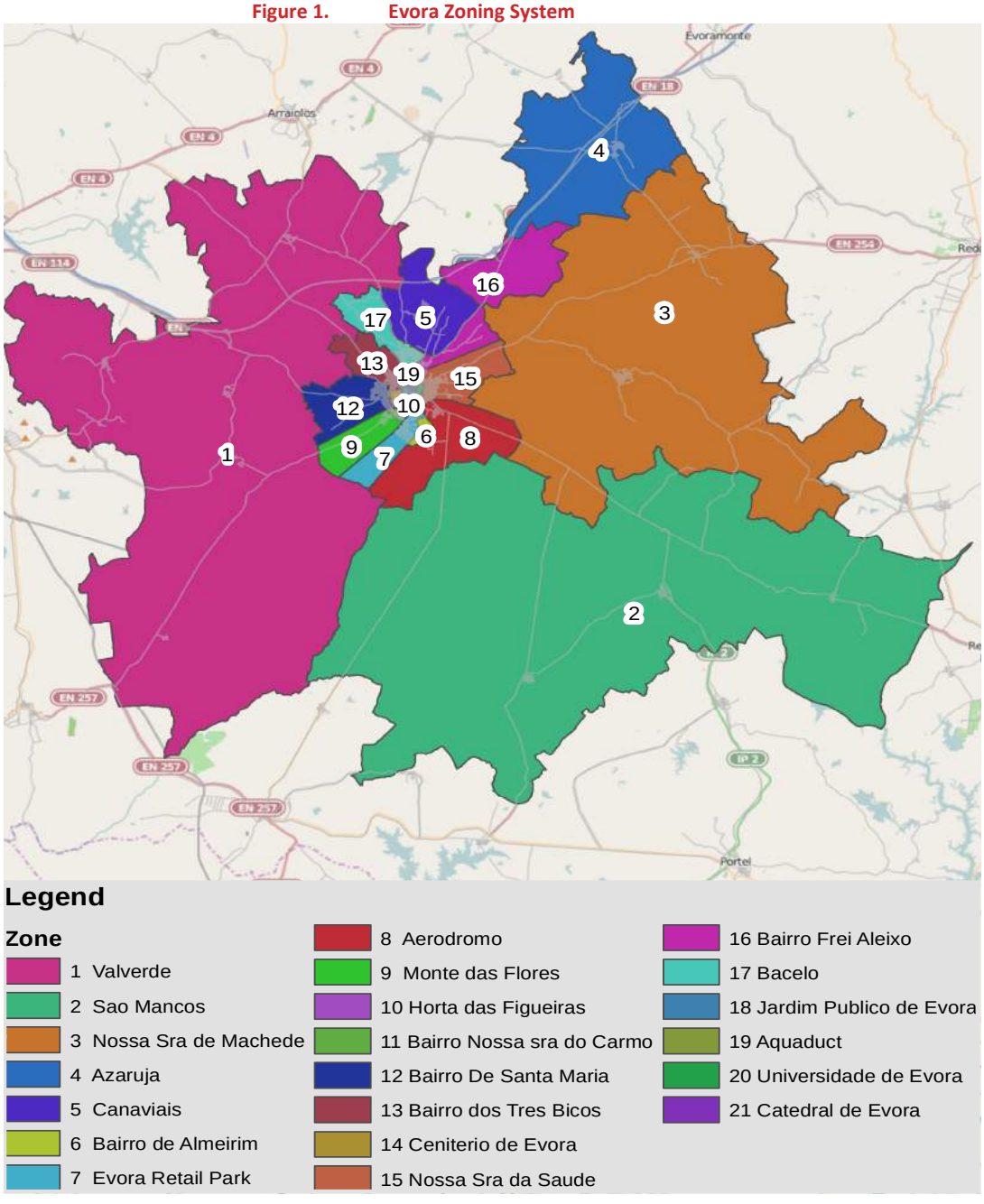


Figure 2. Evora Zoomed Zoning System

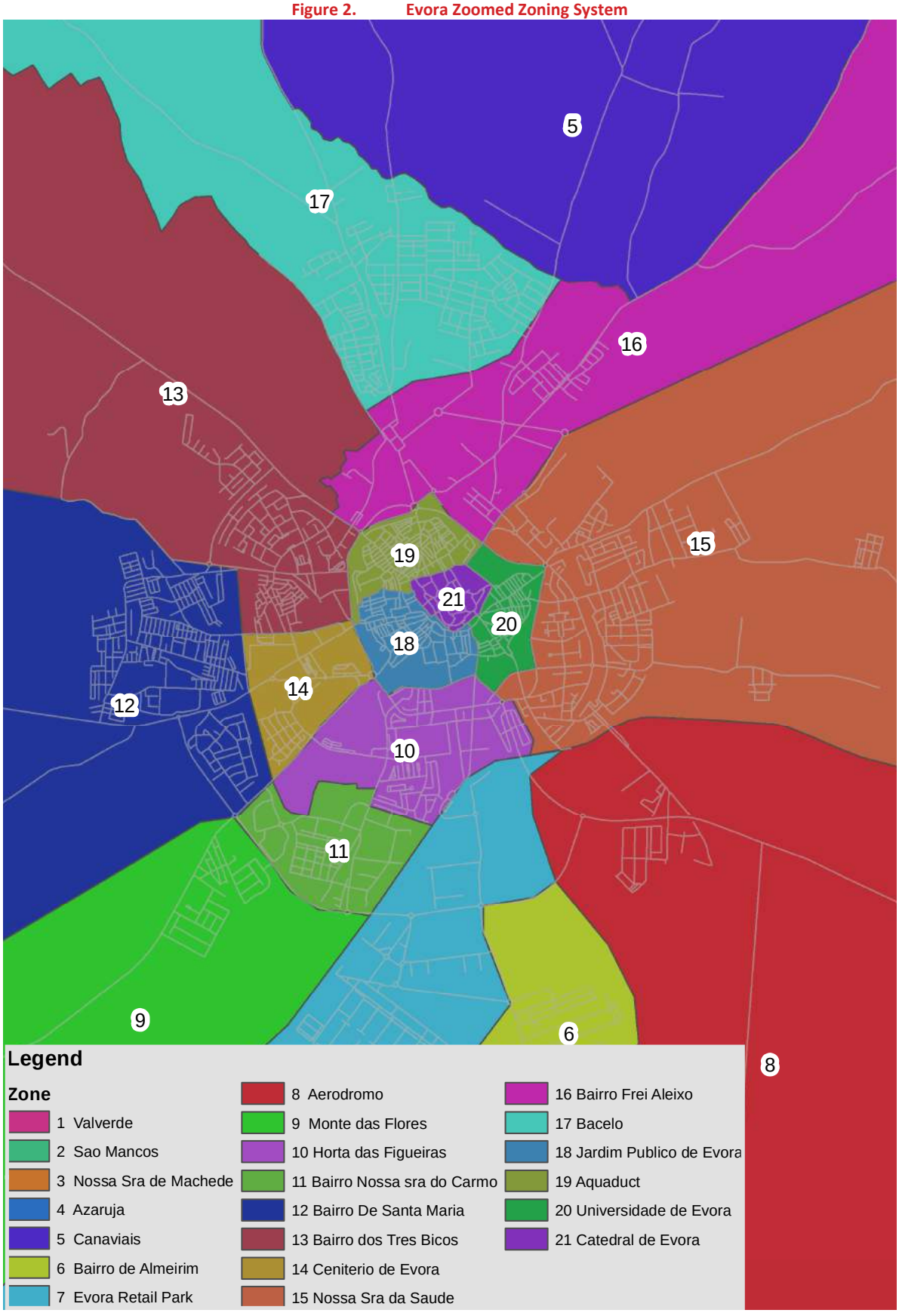
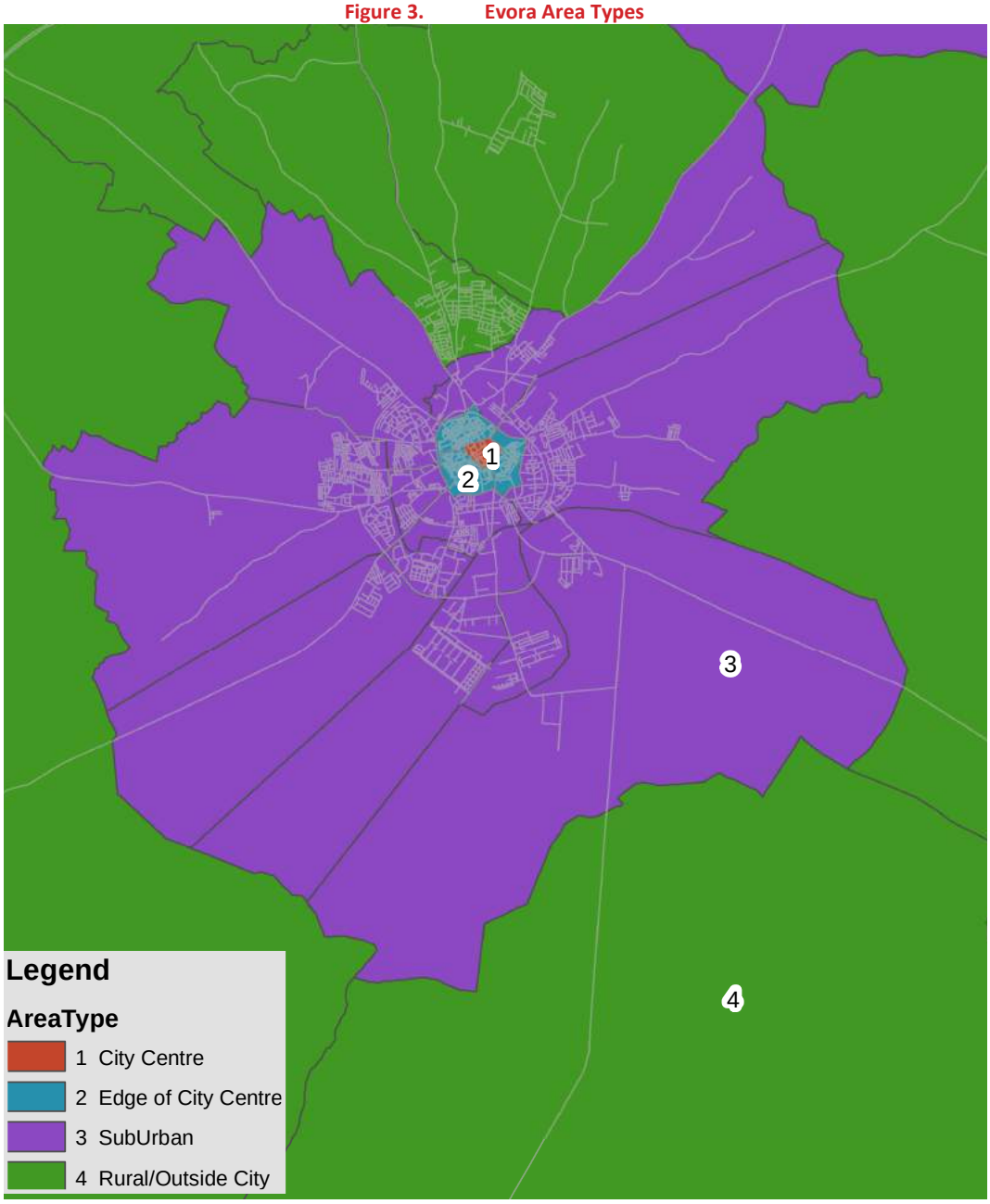


Figure 3. Evora Area Types



2. EXECUTIVE SUMMARY/CONCLUSIONS

2.1 Introduction

2.1.1 This section of the report aims to summarise the key aspects of the model outputs from the base year model run. They can be split into three different types of outputs:

- Demand Outputs;
- Energy Consumption Outputs; and
- Emissions Outputs.

2.1.2 A more detailed analysis of these outputs is presented in the main outputs section.

2.2 Demand Outputs

2.2.1 The total person demand in Evora is 166,833, which using average city-specific vehicle occupancies, equates to around 129,142 vehicles. This is on average 2.9 trips per person, with an average distance of around 6km. Figure 4 shows the number of vehicles broken down by type.

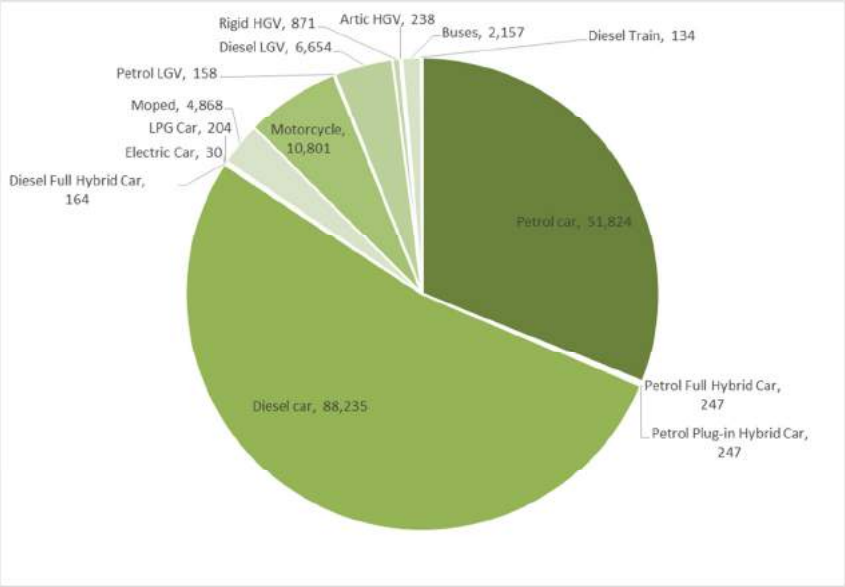


Figure 4. Demand By Vehicle Type

2.3 Energy Consumption Outputs

2.3.1 The following table shows how the total energy used in the Evora based year model run is split by mode, as well as how much energy is used per person, per trip or a combination of both. All of the energy usage outputs are per day.

2.3.2 Table 1 presents a summary of the total energy used by transport within Evora. The total daily value across all modes, vehicle types, purposes and zones is **3,900,627 MJ**, which is around 69MJ per person, per day.

2.3.3 It can be seen that nearly all of the total energy used by transport in Evora can be attributed to cars, which represent roughly four fifths of the total demand.

Table 1. Energy Usage Summary

NO	TOTAL	CARS	BIKES	GOODS	BUSES	TRAINS
Total Energy (MJ)	**3,900,627**	**3,421,265**	**102,025**	**269,579**	**59,214**	**48,544**
Population	56,595					
Energy Per Person (MJ)	68.9	60.5	1.8	4.8	1.0	0.9
Demand (Persons)	166,833	140,952	15,668	7,922	2,157	134
Energy Per Trip (MJ)	23.4	24.3	6.5	34.0	27.5	362.3
Trips Per Person	2.9	2.5	0.3	0.1	0.0	0.0
Actual Vehicles	46,048	38,421	5,662	1,481	417	68
Energy Per Vehicle (MJ)	84.7	89.0	18.0	182.0	142.0	713.9
Vehicles Per Person	0.81	0.68	0.10	0.03	0.01	0.001

2.3.4 Figure 5 shows the energy consumption aggregated to the zone the demand originates in. It can be seen that the zones furthest away from the centre (where there are higher numbers of attractions), often have a high energy usage due to the large travel distances, whereas zones which have shorter trip lengths to the centre of Evora, will often have a low energy usage.

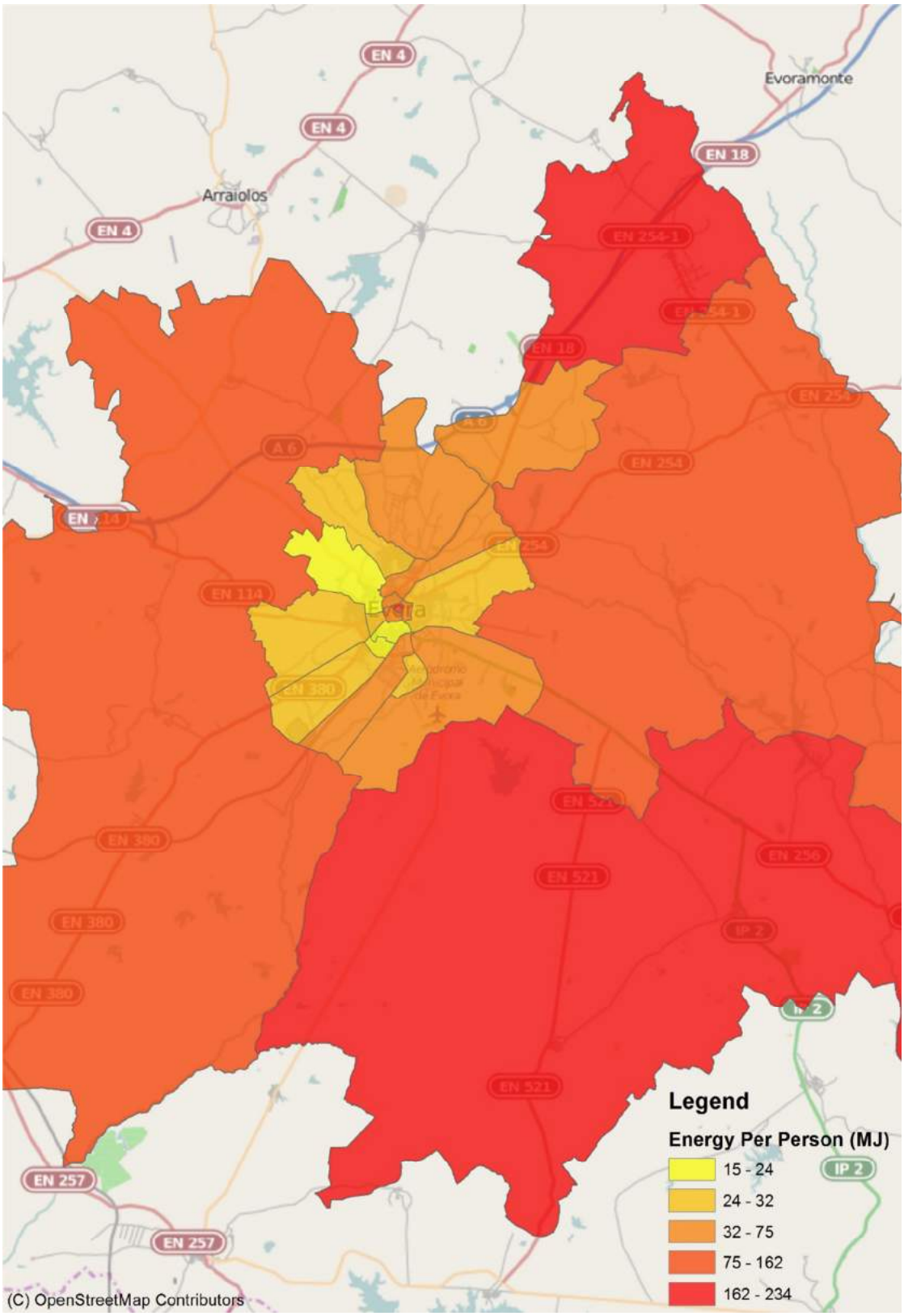


Figure 5. Total Energy (MJ) Per Origin Zone

2.4 Emissions Outputs

2.4.1 The model also reports the following emissions;

- Nitrous Oxides;
- Particulate Matter (PM10s);
- Hydro Carbons;
- Carbon Monoxide; and
- Carbon Dioxide.

2.4.2 Figure 6 demonstrates each of the emission types and the contribution each vehicle type has upon each emission. It can be seen that the splits here are very different depending on the emission type. Mopeds and Motorbikes are responsible for most of the Hydro-Carbons and Carbon Monoxides emitted despite being only a small percentage of the total demand. Diesel cars can be seen to be responsible for the majority of the other emission types.

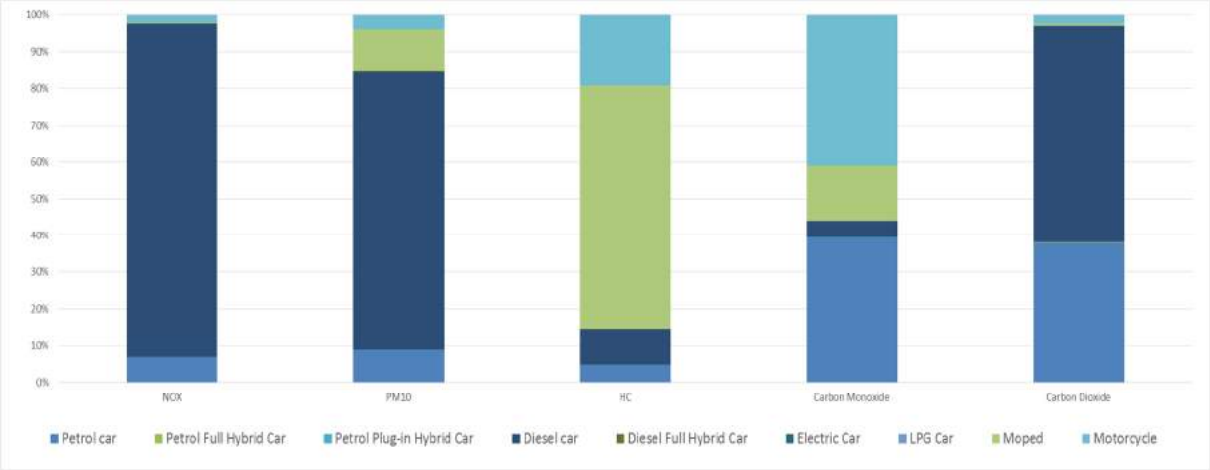


Figure 6. Emissions by Vehicle Type

3. INPUTS

3.1 Introduction

3.1.1 The inputs to the model can be broken down into three sets

- Model specific inputs such as zoning, distances, public transport services, land use;
- Inputs common to all models such as trip purposes, vehicle types, modes etc.
- Parameters for the energy and emissions calculations and for the various transport choices (mode, destination, route)

3.1.2 This report covers only the first set – model specific inputs. In the following sections information is given on the main model-specific inputs and their sources. Inputs included are

- Land Use – Residential and Non-Residential
- Public Transport Routes
- Distances
- Speeds
- Purpose Splits
- Vehicle Type Splits
- Public Transport Fares
- Parking Charges; and
- Internal/External Demand splits.

3.2 Land Use

3.2.1 The land use is one of the most important inputs in the model. The number of dwellings, split into houses and flats, is multiplied by an average trip rate to give a total number of home-based trips per zone. These trips are then distributed amongst the non-residential land use locations based on journey time and the relative attractiveness and size of the non-residential attractors.

Residential

3.2.2 The number of houses and flats in each zone were provided by Evora. The average occupancy per zone was found to be 2.60 across the city.

3.2.3 Table 2 shows the population and number of houses and flats by zone. Figure 3 and 4 show the same information graphically, with the second zooming in on the city centre. It can be seen that there are very few flats throughout the entire region, with the highest proportions being just outside the historic centre.

Table 2. Population and Residential Land Use

NO	ZONE NAME	POP	HOUSES	FLATS	TOTAL	OCC
1	Valverde	2,719	1,337	27	1,364	1.99
2	Sao Mancos	2,017	1,198	13	1,211	1.67
3	Nossa Sra de Machede	1,917	1,102	12	1,114	1.72
4	Azaruja	1,151	685	14	699	1.65
5	Canaviais	3,442	1,128	25	1,153	2.99
6	Bairro de Almeirim	1,461	540	10	550	2.66
7	Evora Retail Park	76	33	3	36	2.11
8	Aerodromo	388	144	3	147	2.64
9	Monte das Flores	1,342	434	11	445	3.02
10	Horta das Figueiras	3,465	465	201	666	5.20
11	Bairro Nossa sra do Carmo	1,160	412	34	446	2.60
12	Bairro De Santa Maria	8,656	2,492	126	2,618	3.31
13	Bairro dos Tres Bicos	4,637	1,123	195	1,318	3.52
14	Ceniterio de Evora	1,187	377	32	409	2.90
15	Nossa Sra da Saude	8,589	2,931	269	3,200	2.68
16	Bairro Frei Aleixo	2,113	766	76	842	2.51
17	Bacelo	7,533	2,093	141	2,234	3.37
18	Jardim Publico de Evora	1,312	1,015	63	1,078	1.22
19	Aquaduct	2,262	1,345	97	1,442	1.57
20	Universidade de Evora	934	570	41	611	1.53
21	Catedral de Evora	233	168	15	183	1.27
	Total	56,595	20,358	1,408	21,766	2.60

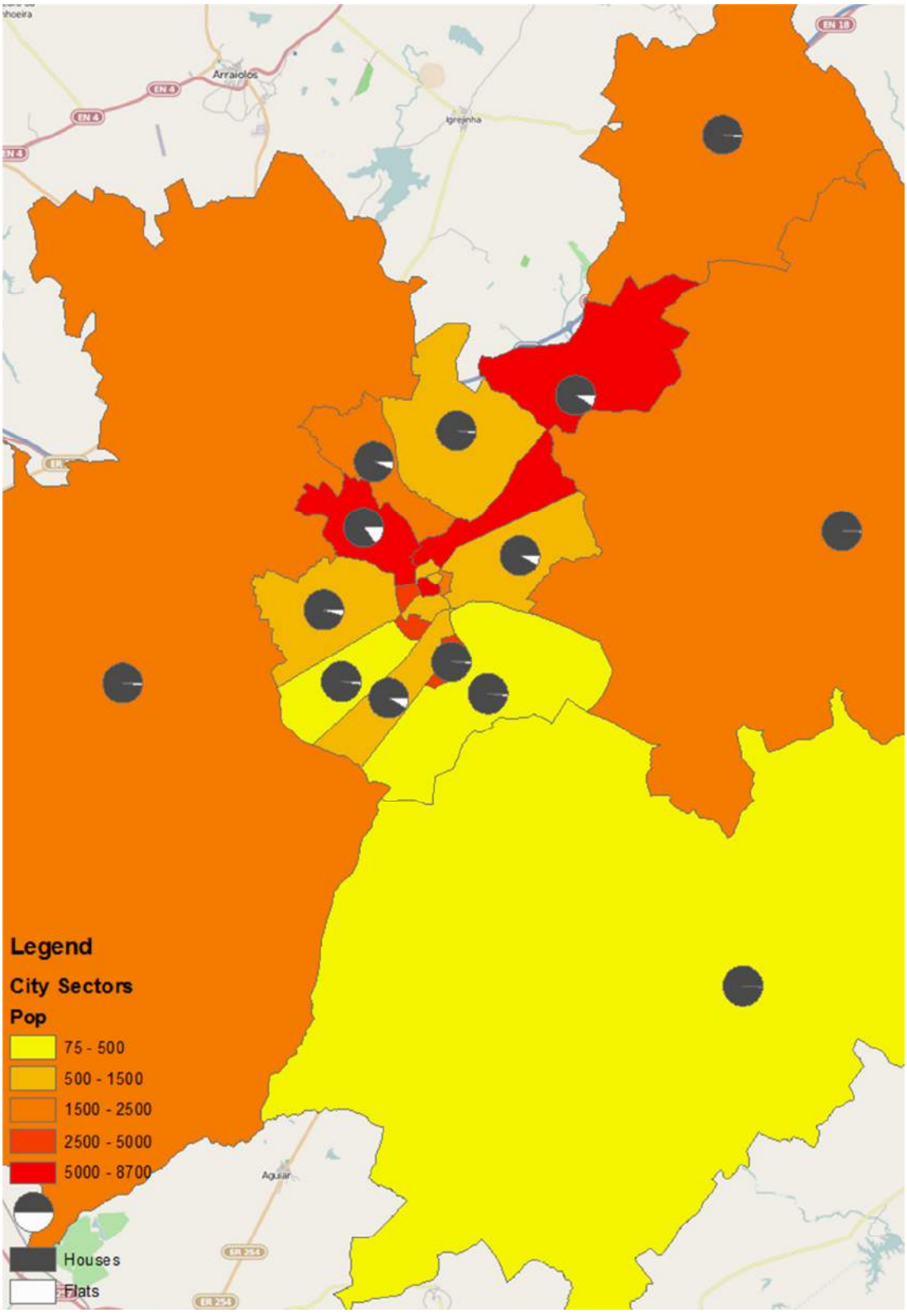


Figure 7. Population and Household Type Splits

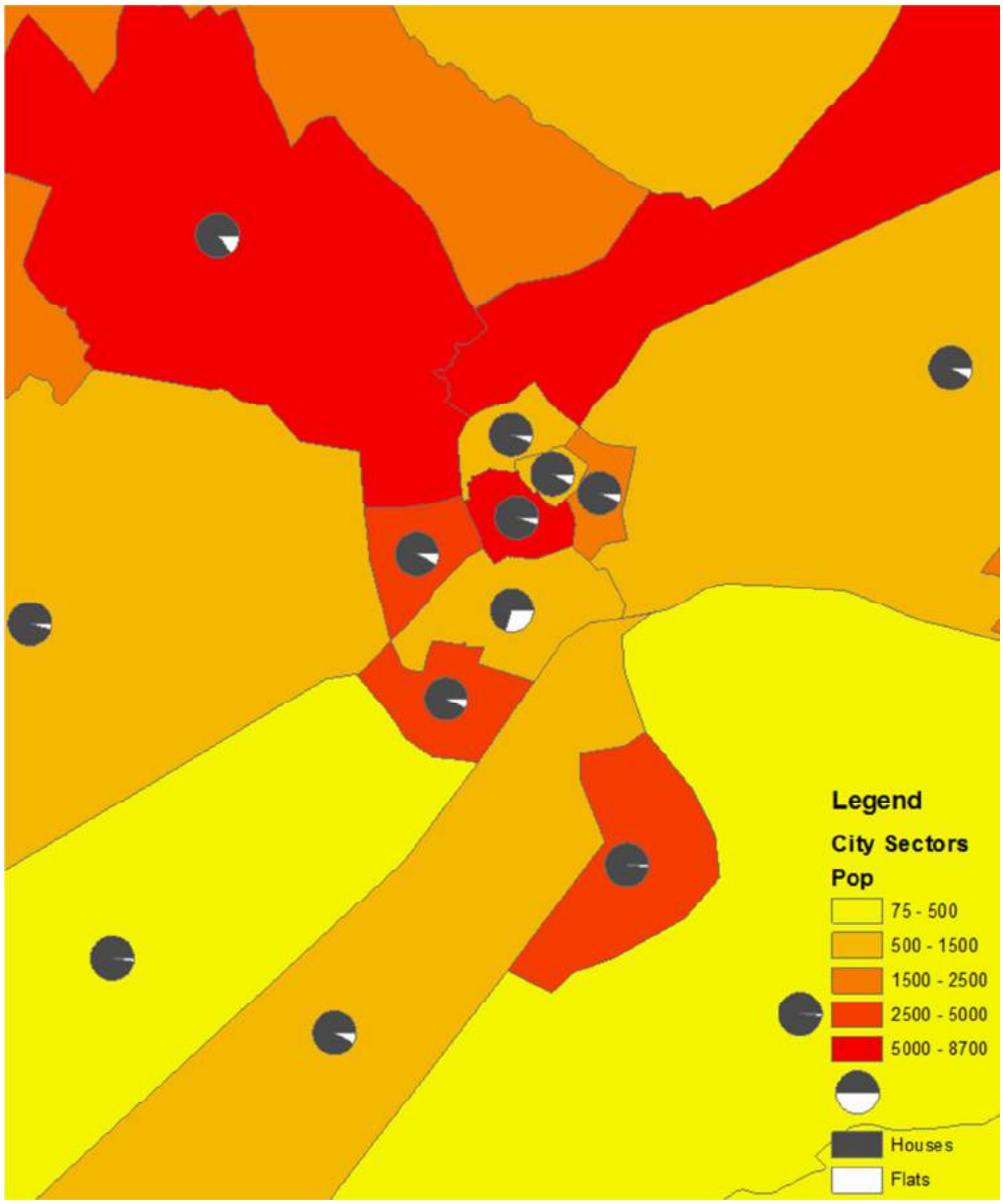


Figure 8. Population and Household Type Splits (Zoomed)

Non-Residential:

3.2.4 Table 3 shows the non-residential land use. The data is input to the model at a more disaggregate level, but is summarised here for clarity. Full details of the assumed land use splits can be found in Appendix A.

3.2.5 No information was provided so all land use was identified through a GIS process. This process has potentially under-estimated the amount of land use, particularly smaller scale developments such as shops and restaurants.

3.2.6 In particular it should be noted that zones 1, 2, 3, 9 and 17 contain no non-residential land use at all and therefore will attract no demand to them.

Table 3. Non-Residential Land Use

NO	ZONE NAME	WORK	SHOPPING	EDUCATION	OTHER
1	Valverde	-	-	-	-
2	Sao Mancos	-	-	-	-
3	Nossa Sra de Machede	-	-	-	-
4	Azaruja	-	-	-	69,863
5	Canaviais	-	-	-	47,711
6	Bairro de Almeirim	258,538	-	3,621	-
7	Evora Retail Park	520,394	218,686	-	-
8	Aerodromo	93,272	16,902	-	46,001
9	Monte das Flores	-	-	-	-
10	Horta das Figueiras	-	-	11,708	308,281
11	Bairro Nossa sra do Carmo	316,035	292,131	-	-
12	Bairro De Santa Maria	63,374	46,780	12,658	227,341
13	Bairro dos Tres Bicos	-	-	77,154	1,212
14	Ceniterio de Evora	-	10,275	89,599	-
15	Nossa Sra da Saude	-	11,162	75,541	26,217
16	Bairro Frei Aleixo	208,532	20,884	33,790	3,206
17	Bacelo	-	-	63,593	-
18	Jardim Publico de Evora	-	-	22,600	41,649
19	Aquaduct	-	296	8,000	10,085
20	Universidade de Evora	-	679	18,600	42,874
21	Catedral de Evora	-	-	-	8,702
	Total	1,460,145	617,795	416,864	833,142

3.2.7 Figure 9 shows the land use figures as percentages of the total zonal land use. Zones outside the image have no non-residential land use.

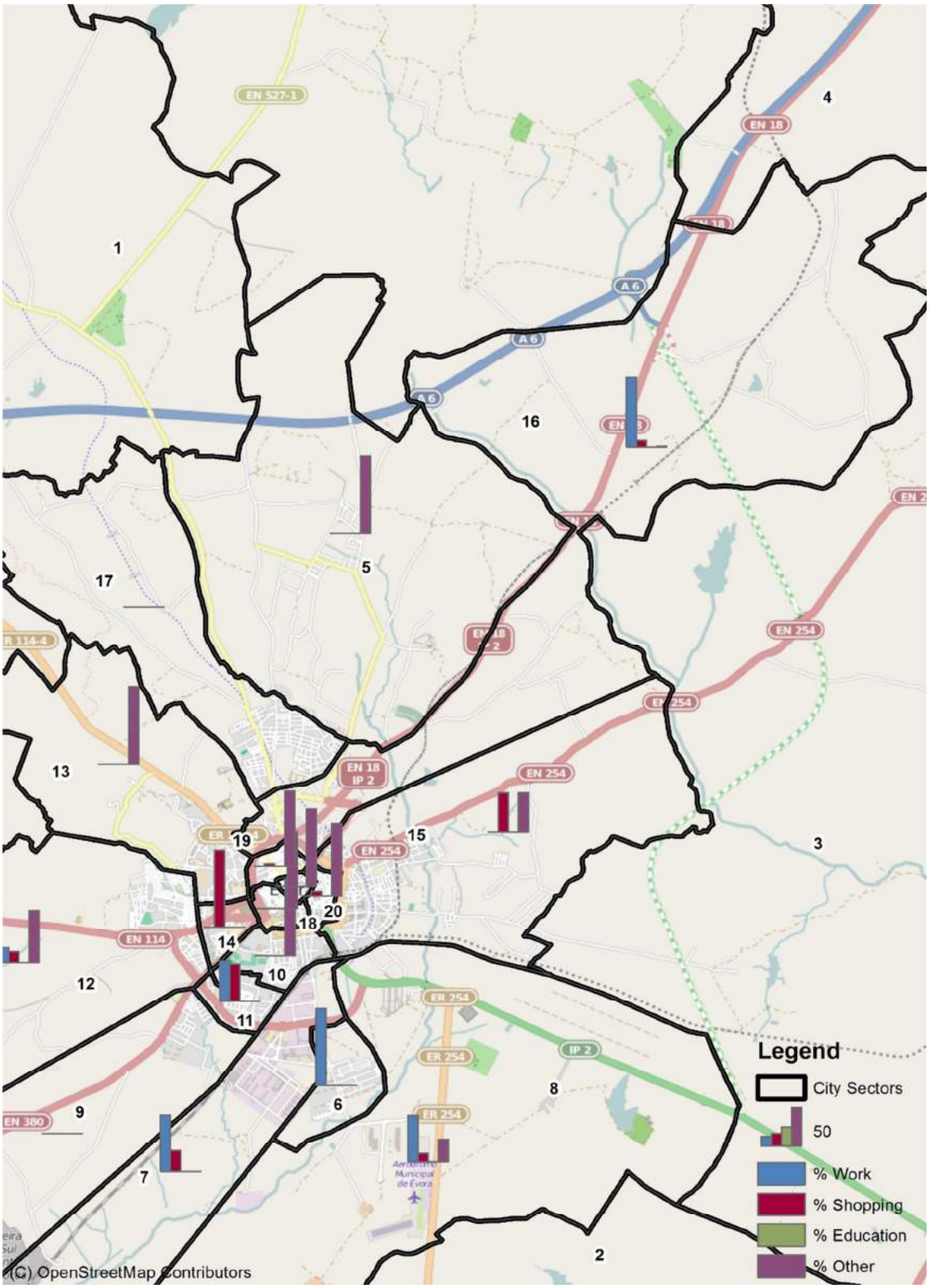


Figure 9. Percentage Land Use by Zone

3.3 Distances

3.3.1 The model calculates average travel times between zones using the average zone-zone distance and speeds. These distances have been obtained via an online routing service, choosing the most common route between the centre of each zone. The public transport distances follow the bus and rail service routes.

3.3.2 Figure 10 shows the Highway routes used, with the route between zones 5 and 8 highlighted as an example. For the highway all movements are possible between all origin-destination combinations. As the Public transport distances have to follow Public Transport routes there are some movements where travel is not possible, and so no distance exists. This is particularly true for rail where the only movement is from zone 10 to the external zone 22. The zones furthest from the centre (zones 1 to 4) are not served by any public transport services at all.

3.3.3 Distances to external zone are taken as the average distance from the Transport Survey to locations outside the study area.

3.3.4 Table 4 to Table 6 show the input distance matrices for highway, bus and rail respectively.

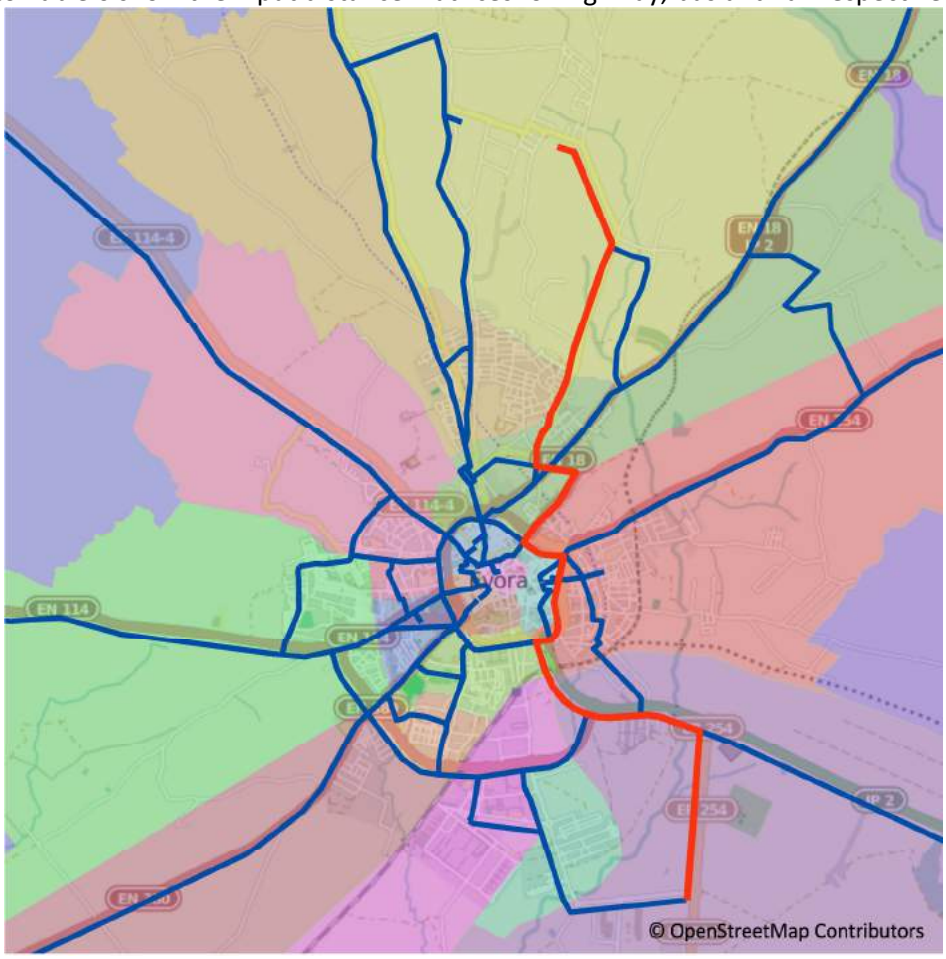


Figure 10. Highway Distances

Table 4. Highway Distances

Highway	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	5.9	37.2	29.2	31.1	20.9	15.1	14.2	18.0	11.8	13.5	13.4	13.6	16.9	14.8	17.9	20.9	18.3	15.4	16.4	17.7	16.8	85.4
2	37.2	12.1	25.9	44.4	31.4	25.6	25.6	24.2	27.0	26.5	26.1	27.8	27.4	26.4	25.1	30.9	28.9	25.9	27.0	25.5	26.7	85.4
3	29.2	25.9	5.8	23.5	17.2	15.7	15.7	16.7	15.9	15.3	16.0	15.7	14.1	14.3	12.4	11.7	14.7	14.5	13.6	12.2	12.9	85.4
4	31.1	44.4	23.5	6.8	19.0	22.6	22.6	23.6	24.0	20.6	21.3	20.8	19.4	19.6	19.3	13.5	20.1	19.9	19.0	19.2	18.9	85.4
5	20.9	31.4	17.2	19.0	2.8	9.2	9.2	10.2	7.6	6.9	7.6	7.1	5.7	5.9	5.8	5.5	3.3	6.2	5.3	5.7	5.5	85.4
6	15.1	25.6	15.7	22.6	9.2	0.5	1.0	1.8	3.2	2.8	2.3	4.4	5.6	4.6	4.1	9.1	7.1	4.1	5.1	3.6	4.9	85.4
7	14.2	25.6	15.7	22.6	9.2	1.0	0.5	2.8	2.3	1.9	1.4	3.5	5.6	4.6	4.1	9.1	7.1	4.1	5.2	3.6	4.9	85.4
8	18.0	24.2	16.7	23.6	10.2	1.8	2.8	0.9	5.0	4.6	4.1	6.2	6.7	5.6	4.3	10.1	8.1	5.1	6.2	4.7	5.9	85.4
9	11.8	27.0	15.9	24.0	7.6	3.2	2.3	5.0	0.8	1.7	1.5	2.2	3.9	2.3	4.0	8.4	5.1	2.1	3.1	3.5	3.5	85.4
10	13.5	26.5	15.3	20.6	6.9	2.8	1.9	4.6	1.7	0.2	0.5	2.9	3.0	1.9	2.4	7.4	4.4	1.4	2.5	1.9	2.9	85.4
11	13.4	26.1	16.0	21.3	7.6	2.3	1.4	4.1	1.5	0.5	0.2	2.7	3.0	1.9	2.9	7.9	4.4	1.4	2.5	2.4	2.9	85.4
12	13.6	27.8	15.7	20.8	7.1	4.4	3.5	6.2	2.2	2.9	2.7	0.9	1.7	2.0	4.1	7.1	4.6	2.6	2.6	4.0	3.0	85.4
13	16.9	27.4	14.1	19.4	5.7	5.6	5.6	6.7	3.9	3.0	3.0	1.7	0.9	1.9	2.8	5.8	3.3	2.2	1.3	2.6	1.7	85.4
14	14.8	26.4	14.3	19.6	5.9	4.6	4.6	5.6	2.3	1.9	1.9	2.0	1.9	1.0	3.0	6.0	3.4	1.2	1.5	2.8	1.9	85.4
15	17.9	25.1	12.4	19.3	5.8	4.1	4.1	4.3	4.0	2.4	2.9	4.1	2.8	3.0	1.2	5.8	3.4	3.2	2.3	0.7	1.6	85.4
16	20.9	30.9	11.7	13.5	5.5	9.1	9.1	10.1	8.4	7.4	7.9	7.1	5.8	6.0	5.8	2.8	6.0	6.4	5.4	5.6	5.4	85.4
17	18.3	28.9	14.7	20.1	3.3	7.1	7.1	8.1	5.1	4.4	4.4	4.6	3.3	3.4	3.4	6.0	1.6	3.7	2.3	3.3	2.7	85.4
18	15.4	25.9	14.5	19.9	6.2	4.1	4.1	5.1	2.1	1.4	1.4	2.6	2.2	1.2	3.2	6.4	3.7	0.7	0.9	3.0	1.2	85.4
19	16.4	27.0	13.6	19.0	5.3	5.1	5.2	6.2	3.1	2.5	2.5	2.6	1.3	1.5	2.3	5.4	2.3	0.9	0.7	1.7	0.7	85.4
20	17.7	25.5	12.2	19.2	5.7	3.6	3.6	4.7	3.5	1.9	2.4	4.0	2.6	2.8	0.7	5.6	3.3	3.0	1.7	1.0	1.4	85.4
21	16.8	26.7	12.9	18.9	5.5	4.9	4.9	5.9	3.5	2.9	2.9	3.0	1.7	1.9	1.6	5.4	2.7	1.2	0.7	1.4	0.8	85.4
22	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	85.4	0.0

Table 5. Bus Distances

Bus	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	1.9	14.0	13.7	0.0	12.3	10.6	11.8	9.2	6.4	7.5	8.1	5.1	3.9	9.4	6.3	7.7	6.6	0.0
6	0.0	0.0	0.0	0.0	14.0	0.5	1.0	0.0	3.3	2.2	2.4	5.4	8.2	7.6	3.8	4.9	6.3	2.8	4.3	3.8	4.6	0.0
7	0.0	0.0	0.0	0.0	13.7	1.0	0.5	0.0	2.3	2.5	1.4	4.4	7.2	6.6	3.8	4.9	6.3	2.9	4.3	3.8	4.6	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	12.3	3.3	2.3	0.0	0.8	1.7	2.0	3.0	5.8	5.2	5.2	4.1	5.5	2.6	3.5	5.2	3.8	0.0
10	0.0	0.0	0.0	0.0	10.6	2.2	2.5	0.0	1.7	0.6	1.1	3.8	2.6	1.4	3.4	3.4	4.9	2.4	2.8	3.3	3.2	0.0
11	0.0	0.0	0.0	0.0	11.8	2.4	1.4	0.0	2.0	1.1	0.6	3.9	3.9	2.7	4.7	4.7	6.2	3.6	4.1	4.6	4.4	0.0
12	0.0	0.0	0.0	0.0	9.2	5.4	4.4	0.0	3.0	3.8	3.9	0.9	1.7	1.9	4.5	4.2	5.7	2.9	2.7	4.3	3.1	0.0
13	0.0	0.0	0.0	0.0	6.4	8.2	7.2	0.0	5.8	2.6	3.9	1.7	0.7	2.3	3.3	1.3	2.8	1.9	1.6	3.1	1.9	0.0
14	0.0	0.0	0.0	0.0	7.5	7.6	6.6	0.0	5.2	1.4	2.7	1.9	2.3	0.2	3.1	2.5	3.9	0.5	1.4	2.6	1.7	0.0
15	0.0	0.0	0.0	0.0	8.1	3.8	3.8	0.0	5.2	3.4	4.7	4.5	3.3	3.1	0.5	5.1	5.7	2.2	3.6	1.0	4.0	0.0
16	0.0	0.0	0.0	0.0	5.1	4.9	4.9	0.0	4.1	3.4	4.7	4.2	1.3	2.5	5.1	0.7	2.7	2.4	5.4	3.5	2.4	0.0
17	0.0	0.0	0.0	0.0	3.9	6.3	6.3	0.0	5.5	4.9	6.2	5.7	2.8	3.9	5.7	2.7	0.0	3.3	2.7	4.2	3.0	0.0
18	0.0	0.0	0.0	0.0	9.4	2.8	2.9	0.0	2.6	2.4	3.6	2.9	1.9	0.5	2.2	2.4	3.3	0.0	1.4	2.9	1.9	0.0
19	0.0	0.0	0.0	0.0	6.3	4.3	4.3	0.0	3.5	2.8	4.1	2.7	1.6	1.4	3.6	5.4	2.7	1.4	0.0	1.5	0.4	0.0
20	0.0	0.0	0.0	0.0	7.7	3.8	3.8	0.0	5.2	3.3	4.6	4.3	3.1	2.6	1.0	3.5	4.2	2.9	1.5	0.3	2.3	0.0
21	0.0	0.0	0.0	0.0	6.6	4.6	4.6	0.0	3.8	3.2	4.4	3.1	1.9	1.7	4.0	2.4	3.0	1.9	0.4	2.3	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 6. Rail Distances

Train	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.1
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

3.4 Public Transport Routes

3.4.1 The main 12 bus routes in Evora are included in the model. Figure 11 shows the routes that the services follow. There are no routes serving zones 1 to 4, or the external zone. Table 6 gives details of the routes included and the number of buses per day.

3.4.2 In addition to the bus services there is a train service from zone 10 to the external zone 22.

3.4.3 Public Transport demand is allowed to take any route that is either direct, or involves one transfer. The route choice model then spreads the demand amongst all the possible routes for a given movement based on the generalised cost of the journey (made up of travel time, wait time, walking time, fare etc).

Figure 11. Public Transport Routes

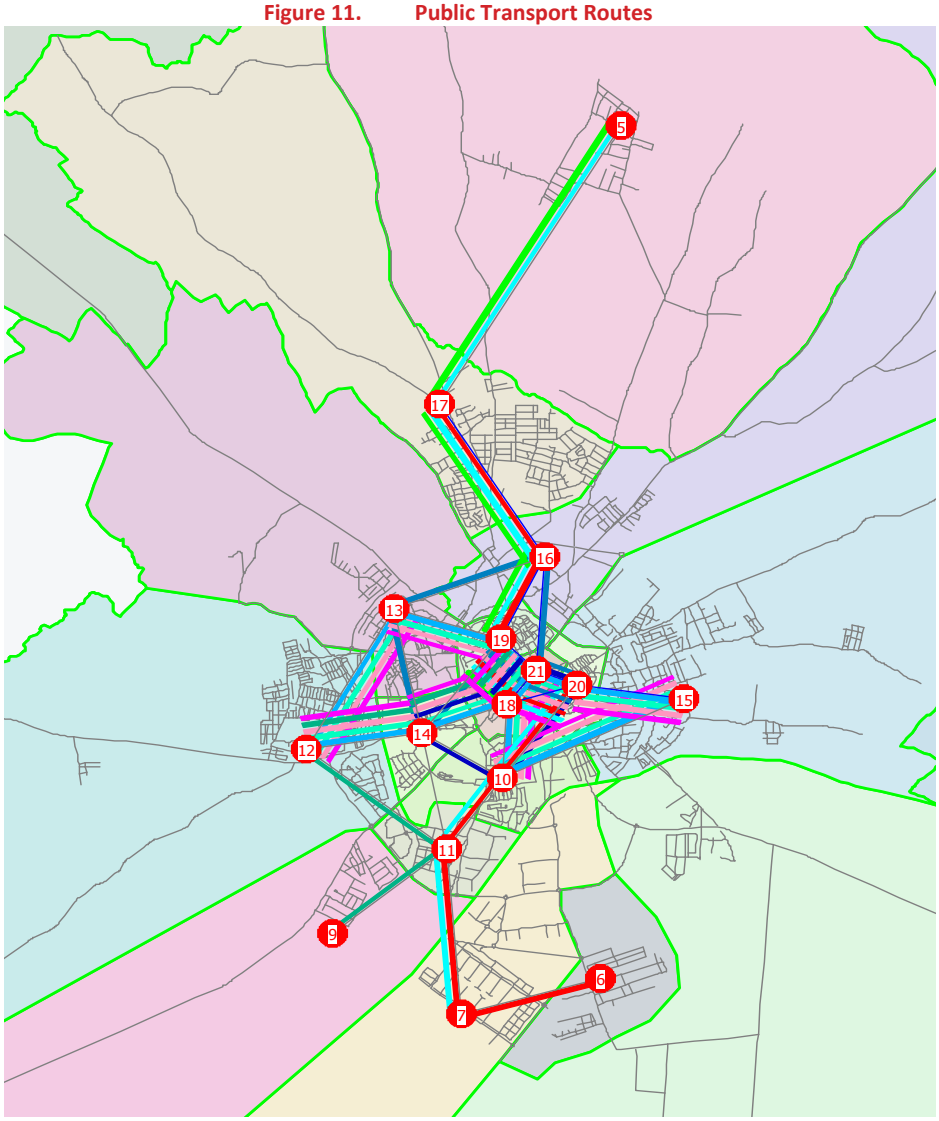


Table 7. Public Transport Routes

ROUTE NO		FROM	TO	ZONE FROM	ZONE TO	BUSES PER DAY
	21	Louredo	Luis de Camões	17	21	18
	22	Canaviais	Parque Industrial (Malagueira)	5	6	14
	23	Garraia	Almeirim	17	6	13
	24	Canaviais	Parque Industrial (C.Histórico)	5	7	15
	25	Canaviais	Luís de Camões	5	21	12
	31	25 de Abril	Malagueira	21	21	11
	32	25 de Abril	Malagueira	15	15	16
	33	Sra.da Saude	Fontanas	15	15	17
	34	Cruz da Picada	Sra da Saude	12	12	11
	41	Gabriel Pereira	Casinha	21	9	12
	51	Circular	Sul	21	21	97
	52	Circular	Norte	14	14	97

3.5 Speeds

3.5.1 The speeds in the model are specified by Vehicle Type and Area Type. Table 8 shows the speeds used in the model, aggregated to groups of vehicle types with the same sets of speed. The groupings are;

- Cars: Petrol, Diesel, Petrol Full Hybrid, Diesel Full-Hybrid, Electric, LPG cars and Taxis.
- Goods Vehicles: Petrol and Diesel LGVs, Rigid and Artic HGVs.
- Buses: Diesel, Hybrid, Electric and Gas-powered buses.
- Trains: Diesel and Electric trains.

Table 8. Speeds by Vehicle and Area Type

VEHICLE TYPE	CITY CENTRE	EDGE OF CITY CENTRE	SUB URBAN	RURAL/ OUTSIDE CITY	EXTERNAL
Cars	30	30	40	70	90
Goods Vehicles	20	20	30	50	50
Buses	30	30	40	70	90
Mopeds/Motorbikes	15	25	30	50	50
Trains	50	50	100	100	100

3.6 Purpose Splits

3.6.1 The home-based trips are split into purposes using zonal purpose splitting factors. These have been calculated from the Transport Survey data. For the Retail and Education purposes where the percentage split was less than the average for the whole city the average split was used. The Work and Other purposes were then factored down to retain 100% across all purposes.

3.6.2 Table 9 shows the zonal purpose splits used, with Figure 12 showing the variation graphically. Figure 13 shows the average purpose splits across the whole city.

Table 9. Residential Purpose Splits

	Zone	Office	Industry / Warehousing	Retail Food	Retail Non-Food	Primary School	Secondary School	College	Other	All Purposes
1	Valverde	46%	14%	15%	19%	1%	4%	2%	0%	100%
2	Sao Mancos	30%	9%	3%	4%	1%	4%	2%	47%	100%
3	Nossa Sra de Machede	22%	7%	3%	4%	1%	4%	2%	57%	100%
4	Azaruja	66%	20%	3%	4%	1%	4%	2%	0%	100%
5	Canaviais	29%	9%	9%	11%	1%	4%	2%	35%	100%
6	Bairro de Almeirim	35%	11%	7%	9%	1%	4%	2%	31%	100%
7	Evora Retail Park	33%	10%	3%	4%	1%	4%	2%	43%	100%
8	Aerodromo	30%	9%	3%	4%	1%	4%	2%	47%	100%
9	Monte das Flores	20%	6%	9%	12%	1%	4%	2%	46%	100%
10	Horta das Figueiras	21%	7%	9%	11%	4%	10%	4%	34%	100%
11	Bairro Nossa sra do Carmo	25%	8%	3%	4%	1%	4%	2%	54%	100%
12	Bairro De Santa Maria	36%	11%	3%	4%	2%	5%	2%	37%	100%
13	Bairro dos Tres Bicos	33%	10%	3%	4%	1%	4%	2%	43%	100%
14	Ceniterio de Evora	7%	2%	13%	17%	1%	4%	2%	54%	100%
15	Nossa Sra da Saude	22%	7%	5%	7%	1%	4%	2%	52%	100%
16	Bairro Frei Aleixo	20%	6%	3%	4%	4%	11%	5%	46%	100%
17	Bacelo	25%	8%	3%	4%	3%	7%	3%	47%	100%
18	Jardim Publico de Evora	33%	10%	3%	4%	1%	4%	2%	43%	100%
19	Aquaduct	52%	16%	3%	4%	5%	14%	6%	0%	100%
20	Universidade de Evora	66%	20%	3%	4%	1%	4%	2%	0%	100%
21	Catedral de Evora	8%	2%	15%	19%	1%	4%	2%	50%	100%
	Average	30%	9%	3%	4%	1%	4%	2%	47%	100%

Figure 12. Residential Purpose Splits By Zone

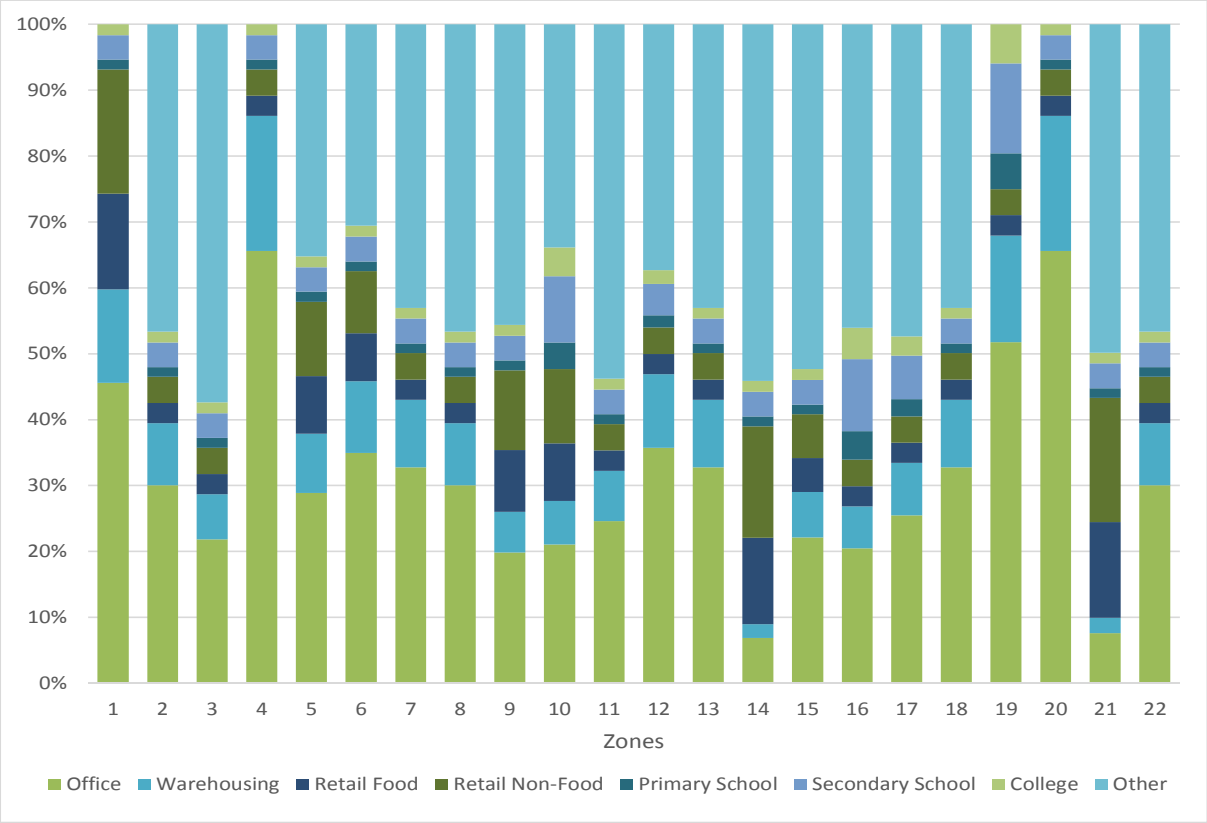
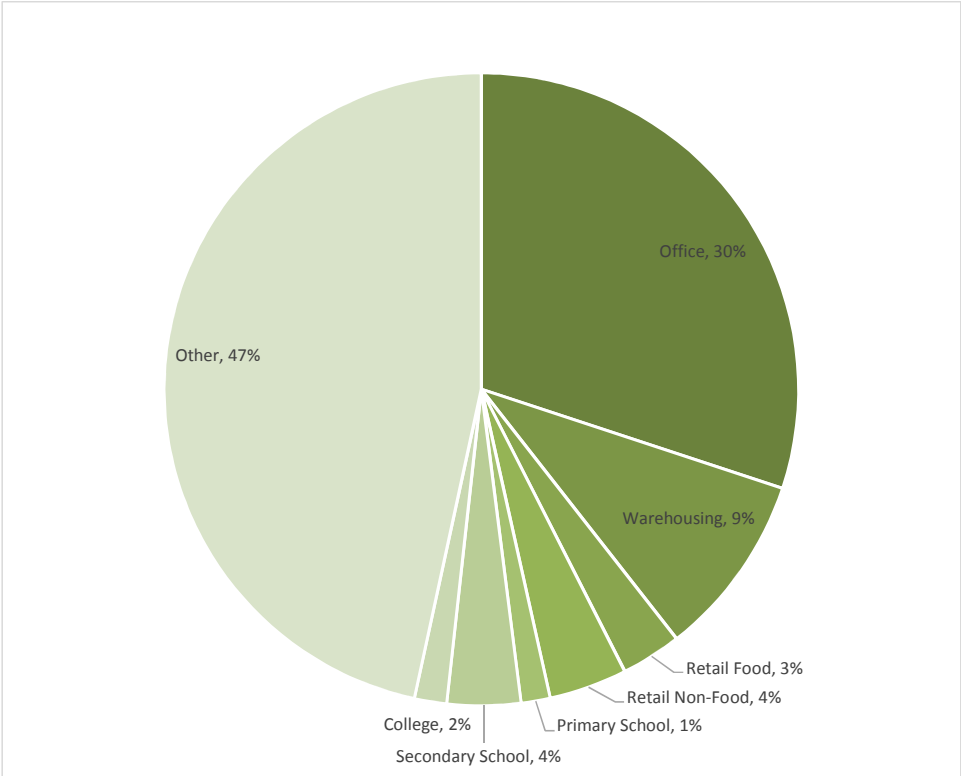


Figure 13. Average Residential Purpose Splits



3.7 Vehicle Splits

3.7.1 The vehicle type splits were calculated using the following process;

- The split between Petrol and Diesel was taken from the Transport and Mobility Survey in Evora. This gave the following splits;
  - Petrol: 37.1%
  - Diesel: 62.6%
- Figures for Hybrid, Electric and Gas-powered cars were calculated from Portuguese sales data from 2001 to 2013. These were taken from the International Council on Clean Transportation website[1]. This gives a share of 0.47% for Hybrids which is then broken down to the different Hybrid types using UK fleet data. The electric share is 0.02% and the LPG share is 0.14%.
- The split between cars and bikes, and between mopeds and motorbikes were taken from the European Commission Statistical Pocketbook 2012[2]. For Portugal this gave the following;
  - 31% of vehicles are motorbikes or mopeds; and
  - 69% of two-wheelers are motorbikes.

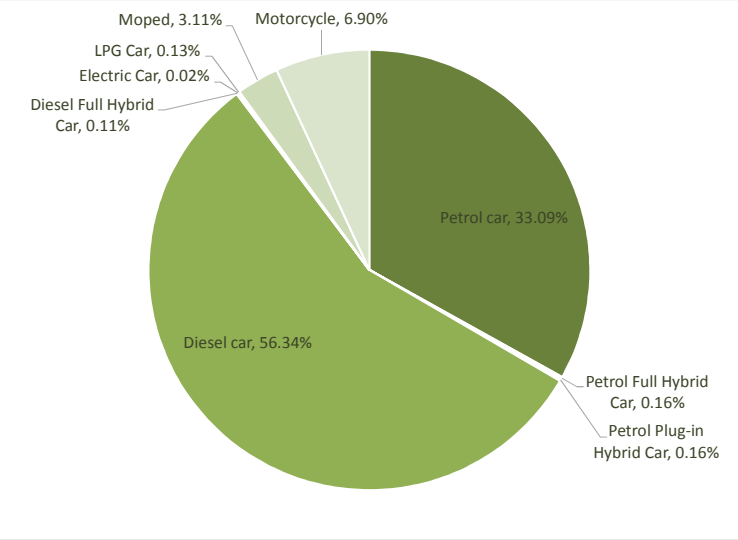
3.7.2 Combining these statistics gives the vehicle splits shown in Table 10 and Figure 14.

Table 10. Vehicle Splits – Highway

ID	VEHICLE TYPE	PERCENTAGE SPLIT
1	Petrol car (incTaxis)	33.09%
2	Diesel car (inc Taxis)	56.34%
3	Petrol Full Hybrid Car	0.16%
4	Diesel Full Hybrid Car	0.11%
5	Petrol Plug-in Hybrid Car	0.16%
6	Electric Car	0.02%
15	Moped	3.11%
16	Motorcycle	6.90%
17	LPG Car	0.13%

[1] http://www.theicct.org/sites/default/files/publications/EU_pocketbook_2014.pdf
[2] http://ec.europa.eu/transport/facts-fundings/statistics/doc/2012/pocketbook2012.pdf

Figure 14. Highway Vehicle Splits

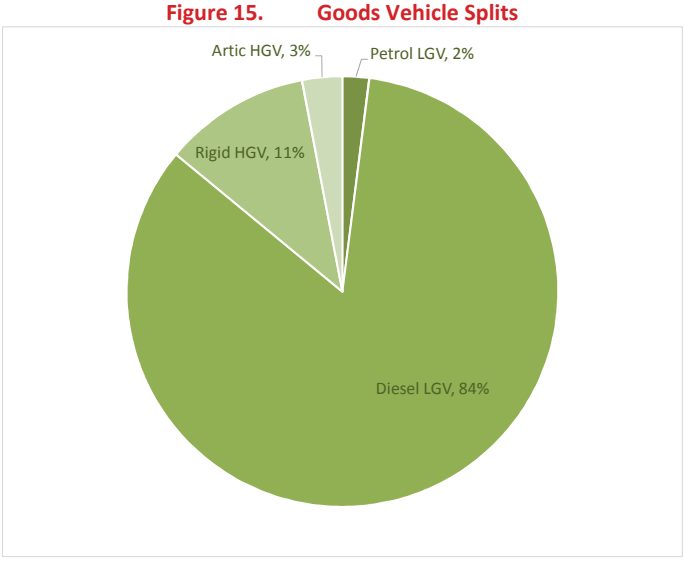


3.7.3 The split between different goods vehicles was taken from 2013 UK fleet split data as no Portuguese data could be sourced. The values used are shown in Table 11 and Figure 15.

Table 11. Goods Vehicle Splits

ID	VEHICLE TYPE	PERCENTAGE SPLIT
7	Petrol LGV	2.00%
8	Diesel LGV	84.00%
9	Rigid HGV	11.00%
10	Artic HGV	3.00%

Figure 15. Goods Vehicle Splits



3.8 Parking

3.8.1 Evora has 10 car parks around the city centre. A parking charge of €0.60 an hour has been assumed. This is based on the cost of parking in Cesena. Details of the car parks are shown in Table 12.

3.8.2 **Note:** There is no modelling of parking capacity within the model. The cost of parking is an additional cost included when travelling to a zone with car parking.

3.8.3 Parking charges represent an average charge incurred by all trips destinating in the zone containing the car park.

3.8.4 To calculate the total cost of parking for each purpose it has been assumed that work-based purposes (Office & Industry/Warehousing) park for an eight hour working day. All other purposes (Retail, Education and Other types) are assumed to park for two hours.

3.8.5 In addition, the charges have been reduced by one third to reflect the availability of work-place parking and free on-street parking. The resulting charges are shown in Table 13.

Table 12. Car Parks In Evora

CAR PARK NAME	CAPACITY	PRICE (€/HR)	ZONE
Parque das Portas da Lagoa	298	€ 0.60	16
Parque das Portas de Avis	600	€ 0.60	16
Parque do PIC	500	€ 0.60	15
Parque do Hospital do Patrocinio	80	€ 0.60	15
Parque do Hospital Distrital	70	€ 0.60	20
Parque do Rossio	1050	€ 0.60	10
Parque doEPRAL	100	€ 0.60	10
Parque da Aminata	250	€ 0.60	10
Parque junto ás Bombas Galp	70	€ 0.60	14
Parque da Estrada das Piscinas	60	€ 0.60	13

Table 13. Parking Charges by Zone

ZONE		WORK	OTHER
10	Horta das Figueiras	€ 3.20	€ 0.80
14	Ceniterio de Evora	€ 3.20	€ 0.80
18	Jardim Publico de Evora	€ 3.20	€ 0.80
19	Aquaduct	€ 3.20	€ 0.80
20	Universidade de Evora	€ 3.20	€ 0.80
21	Cathedral de Evora	€ 3.20	€ 0.80

3.9 Internal & External Demand Splits

3.9.1 The external demand to and from the city is created by factoring the internal demand. This factor is taken from Transport surveys. For Evora the internal percentage is 93% of the total demand. This percentage is applied to highway, PT and goods demand as there is not sufficient information to get individual splits.

3.10 Public Transport Fares

3.10.1 The public transport fares are treated differently for buses and trains. Buses use a fare matrix, giving zone-zone fares. The fare is €1.00 for journeys between zones 5 to 21 (those which are currently served by a bus). The fare to the remaining zones (1-4 and 22) is €2.00, though this is not currently used. The full fare matrix is shown in Table 14.

3.10.2 The rail fares are distance based and use a price per km, which is multiplied by the distance travelled to get the fare. The cost per km was calculated using the fare from Evora to Lisbon, which is €12.00 (taken from http://uk.voyages-sncf.com/en/) and covers approximately 130km. This gives a cost per km of €0.09 per km.

Table 14. Bus Fares By Zones

ZONES	1-4	5-21	22
1-4	€ 2.00	€ 2.00	€ 2.00
5-21	€ 2.00	€ 1.00	€ 2.00
22	€ 2.00	€ 2.00	€ 2.00

4. CALIBRATION

4.1 Introduction

4.1.1 The model has been calibrated based on the Transport Survey data by looking at mode shares and average trip lengths. The quality of the public transport calibration is limited by the lack of data for this mode in the survey, which it is felt is under-represented. Only 12 trips were recorded as using public transport – none at all for retail purposes. This compares to 378 records for highway trips.

4.2 Mode Share

4.2.1 The Transport Survey has a car mode share of 98% across all zones and purposes. The model has a mode share of 99% which is an acceptable correlation to the observed situation.

4.2.2 Figure 16 shows the global modelled mode share. Figure 17 shows the mode share by purpose, with the work-based purposes having the highest car share.

Figure 16. Global Mode Share

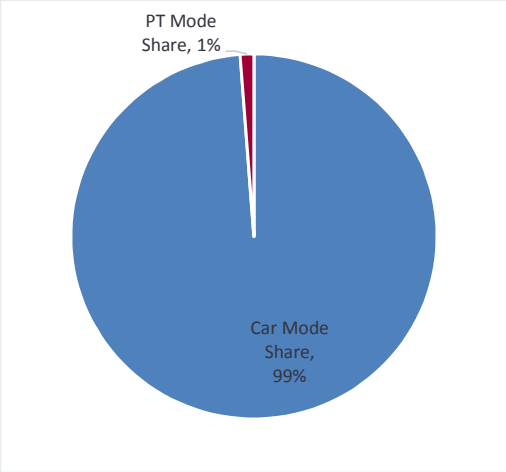
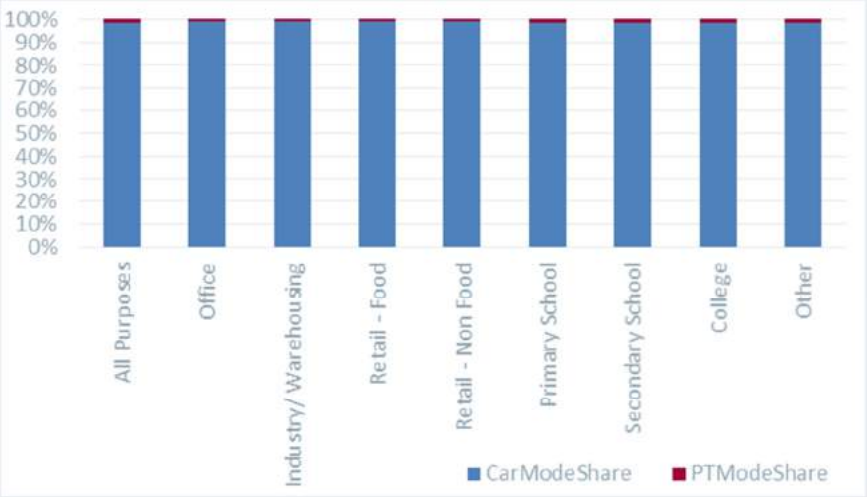


Figure 17. Mode Share by Purpose



4.3 Trip Length Distributions

4.3.1 The Transport Survey has average trip lengths for private vehicles (cars and motorbikes/mopeds) and public transport of 6.26km and 2.90km respectively. The modelled values are 6.59km and 4.17km.

4.3.2 The match for private vehicles to both average trip lengths and the overall trip length distribution is very good. Figure 18 shows the relative and cumulative frequencies of the

observed and model distributions. Figure 19 shows the average trip lengths by purpose, which also show a good match for most purposes, with retail trips being longer than observed.

Figure 18. Highway Trip Length Distributions

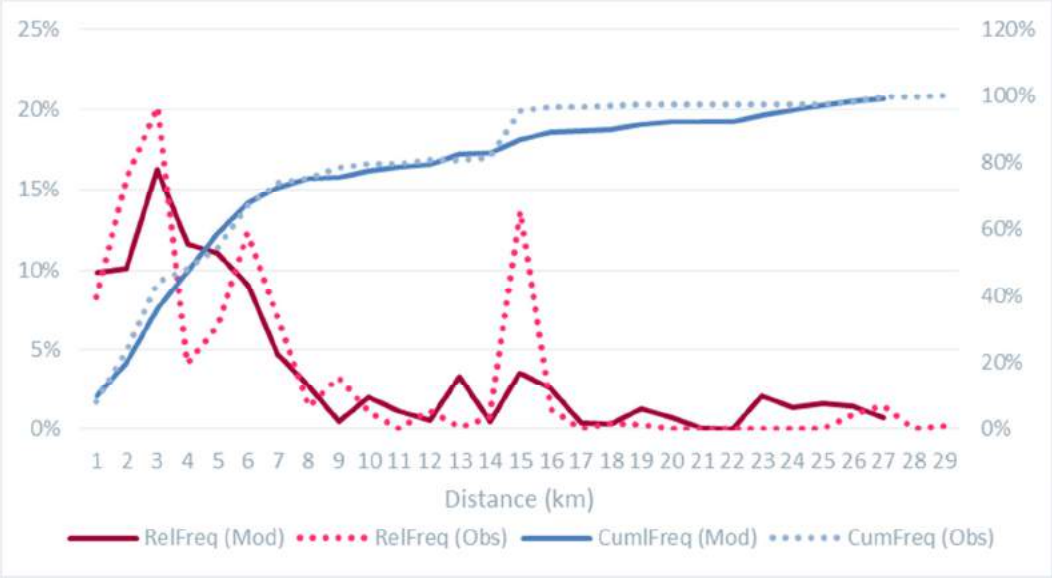
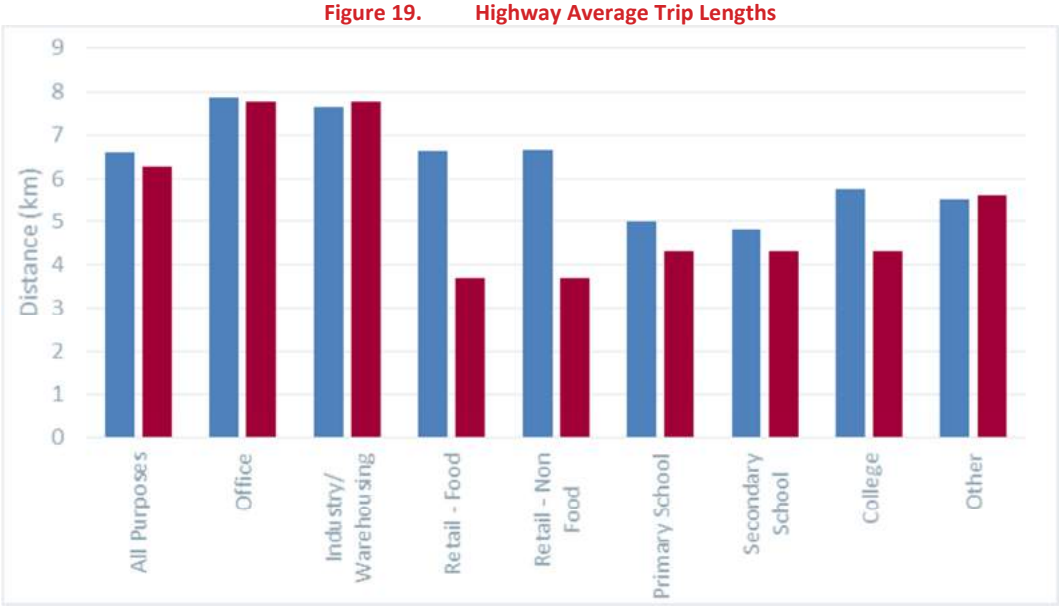


Figure 19. Highway Average Trip Lengths



4.3.3 The public transport distributions show a less good match, under-estimating the number of short distance trips. Figure 20 showing the distribution and Figure 21 showing the average trip lengths by purpose both show this.

4.3.4 However, Figure 20 also highlights the lack of public transport observed data as there are no trips at all for retail purposes. In addition, there are only two Education trips in the Transport Survey demand. One of these trips is over 10km in distance, leading to a higher than expected average trip length, for which no attempt to meet has been made.

Figure 20. Public Transport Trip Length Distributions

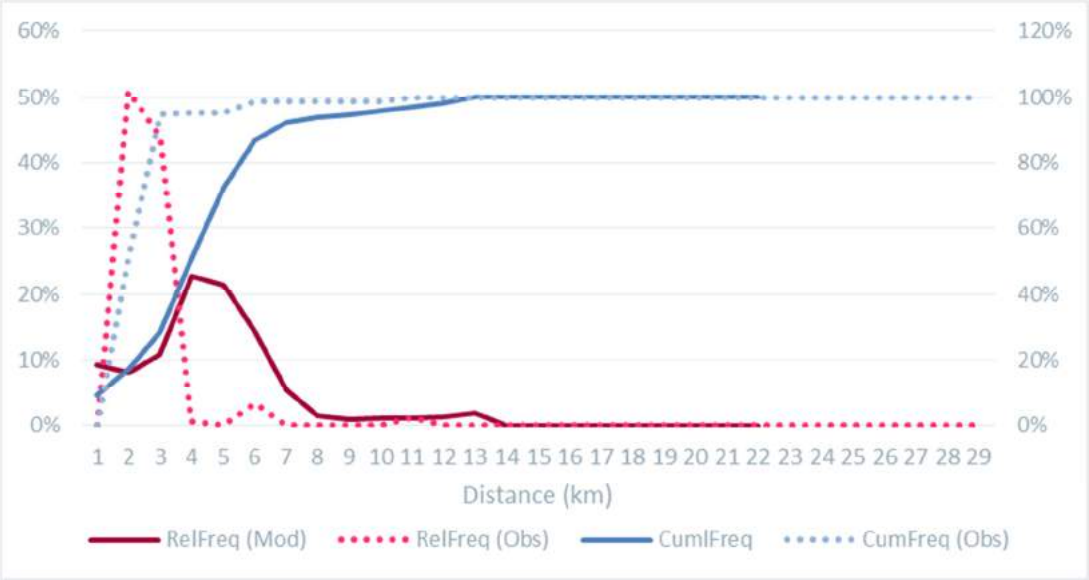
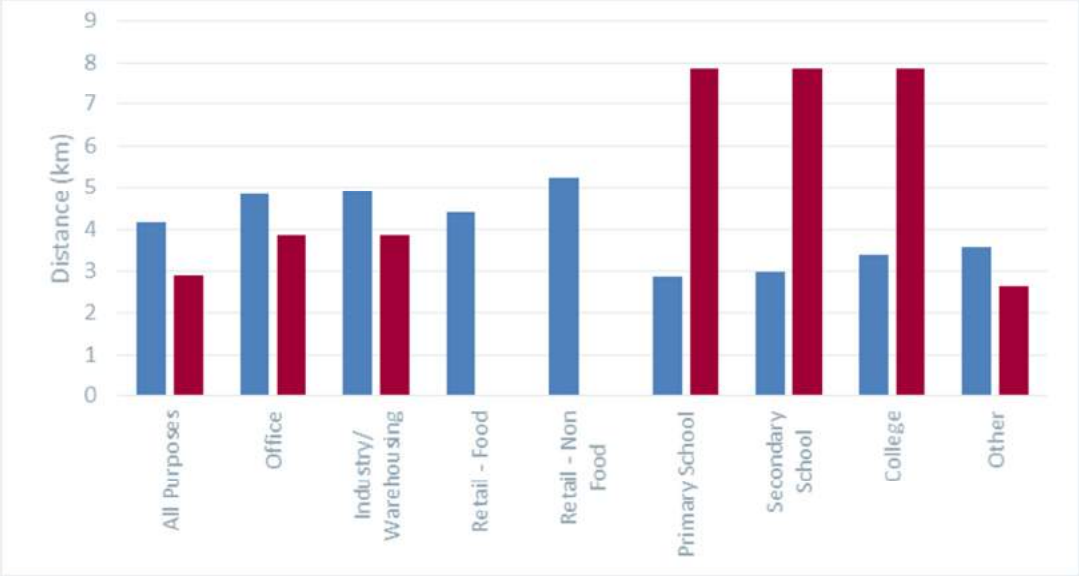


Figure 21. Public Transport Average Trip Lengths



5. OUTPUTS

5.1 Introduction

5.1.1 This section looks at the outputs from the base year model run. It is split into three sections

- **Demand Outputs** – by Origin, Destination, Vehicle Type and a comparison to actual vehicle numbers;
- **Energy Consumption Outputs** – Total energy, per person, per trip and split by vehicle type; and
- **Other Emissions Outputs** – Carbon Dioxide, Hydro Carbons, PM10s and Nitrous Oxide emissions.

5.2 Demand Outputs

5.2.1 This sections looks at the various demand outputs, checking they are sensible and realistic. These include;

- Origin & Destination Plots
- Demand by Purpose and Vehicle Type
- Trip Rate checks
- Comparison to actual vehicle figures
- Zone-Zone demand matrices

5.2.2 Figure 22 shows the Origins and Destinations of the demand by zone. The origins match the distribution of houses and flats, as is to be expected as all the trips are home-based.

Figure 22. Origin & Destination Demand

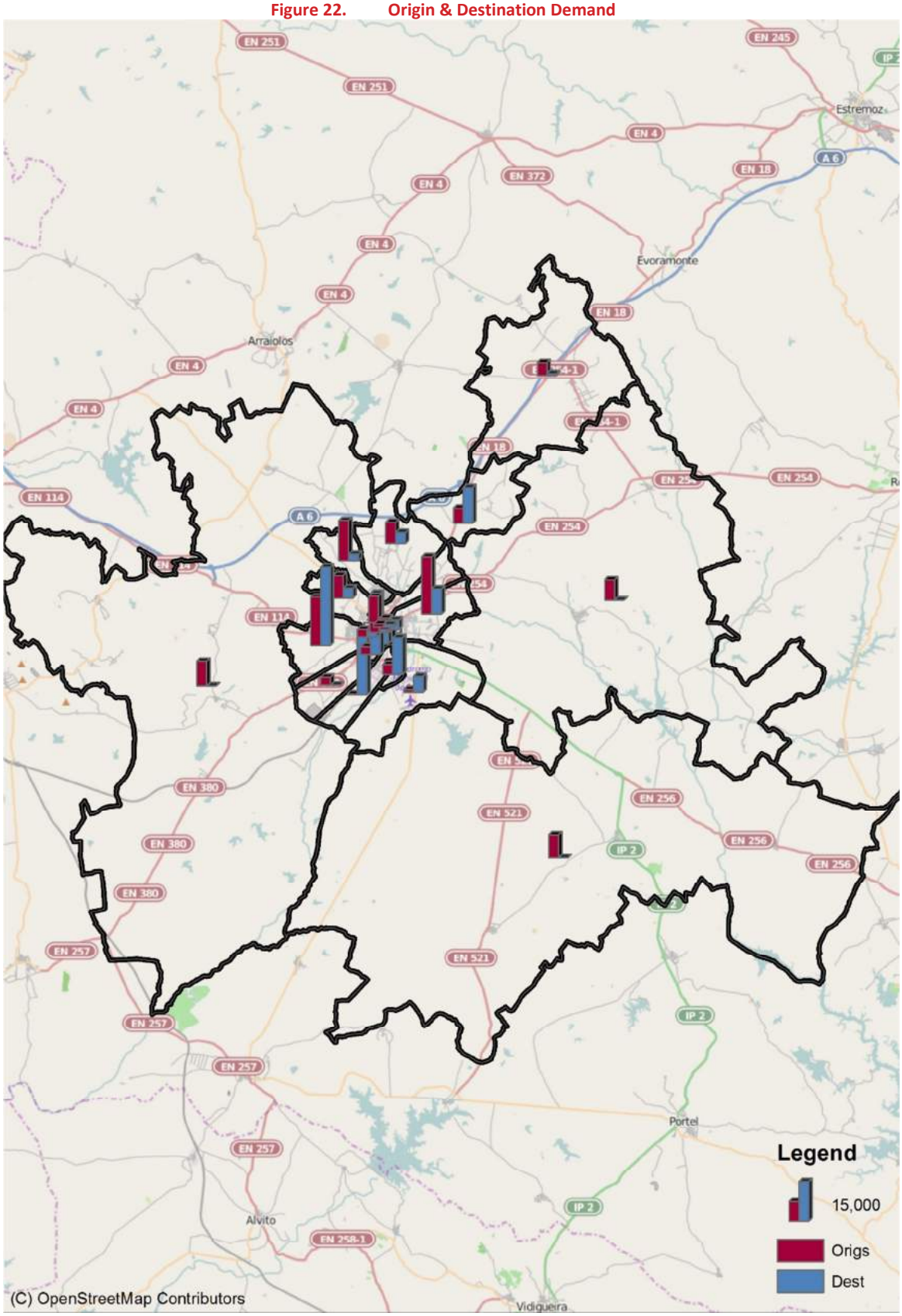
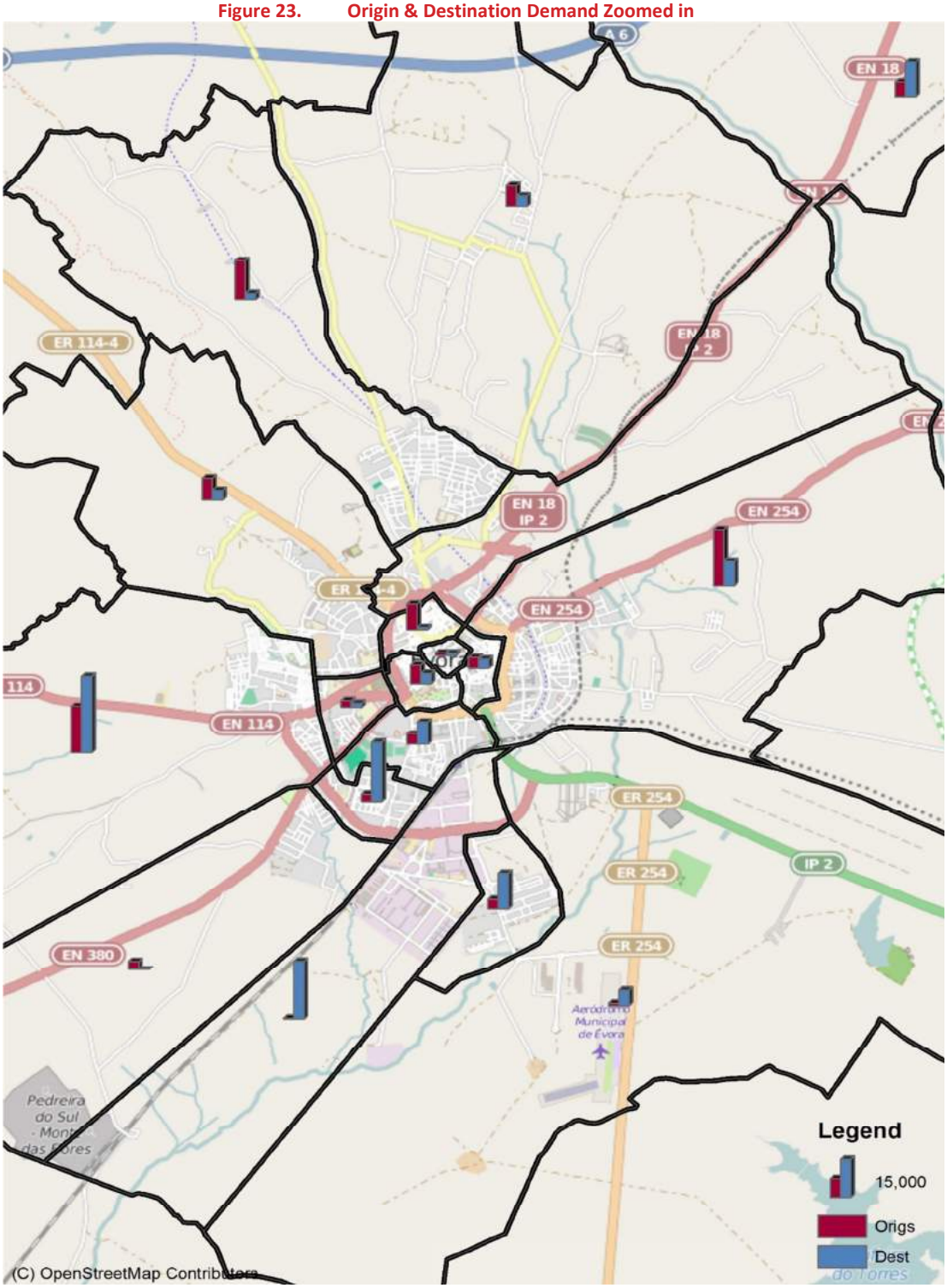


Figure 23. Origin & Destination Demand Zoomed in



5.2.3 Table 15 shows the demand split by purpose and mode (highway and PT). Highway based modes (including cars and motorbikes/mopeds) make up most of the demand, particularly for work based purposes. The public transport mode share is highest for "Other" trips.

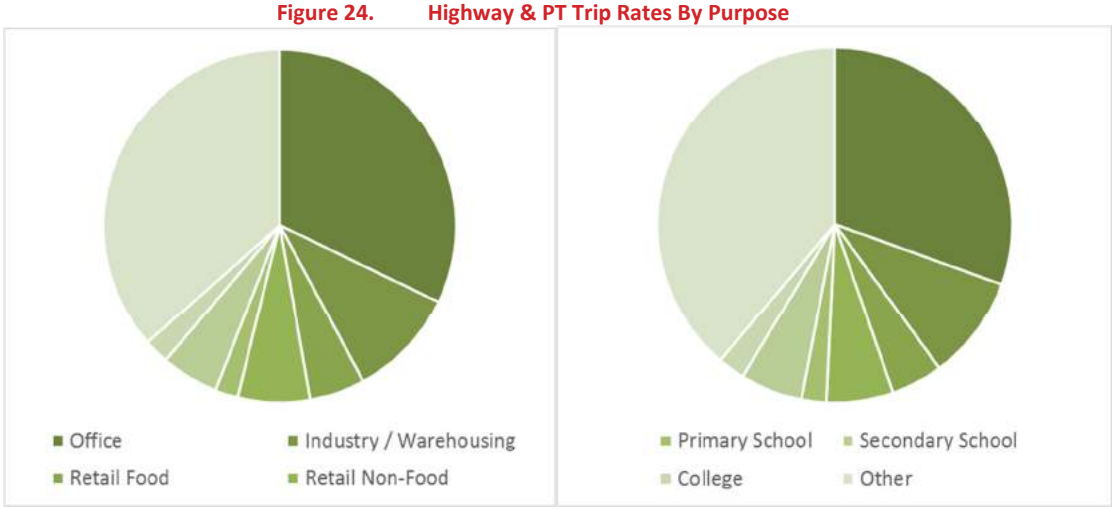
5.2.4 Table 15 also shows the average implied trip rate, per household, for each mode and purpose. Overall there are 2.80 two-way trips made each day per household. This is higher than the 1.5 trips per person from the Transport Survey, though the survey doesn't include retail trips. Comparing the trip rates with Retail removed gives a rate of 2.47 trips per person; again higher than the Transport Survey and potentially suggesting a lower rate of trip making in Portugal than in the UK.

5.2.5 Figure 24 shows the purpose splits of the implied trip rates for each mode, with PT being very similar to Highway as the same splits were assumed due to insufficient PT survey data.

Table 15. Demand and Trip Rates By Purpose

PURPOSE	HIGHWAY DEMAND	PT DEMAND	HY TRIP RATE	PT TRIP RATE	TOTAL TRIP RATE
Commute - Office	50,323	583	0.89	0.010	0.90
Commute - Industrial/Warehousing	15,707	182	0.28	0.003	0.28
Retail - Food	7,967	90	0.14	0.002	0.14
Retail - Non Food	10,331	117	0.18	0.002	0.18
Education - Primary	3,277	43	0.06	0.001	0.06
Education - Secondary	8,236	109	0.15	0.002	0.15
Education - College	3,587	47	0.06	0.001	0.06
Other	57,192	743	1.01	0.013	1.02
Total	**156,620**	**1,914**	**2.77**	**0.034**	**2.80**
Mode Share	99%	1%			

Figure 24. Highway & PT Trip Rates By Purpose



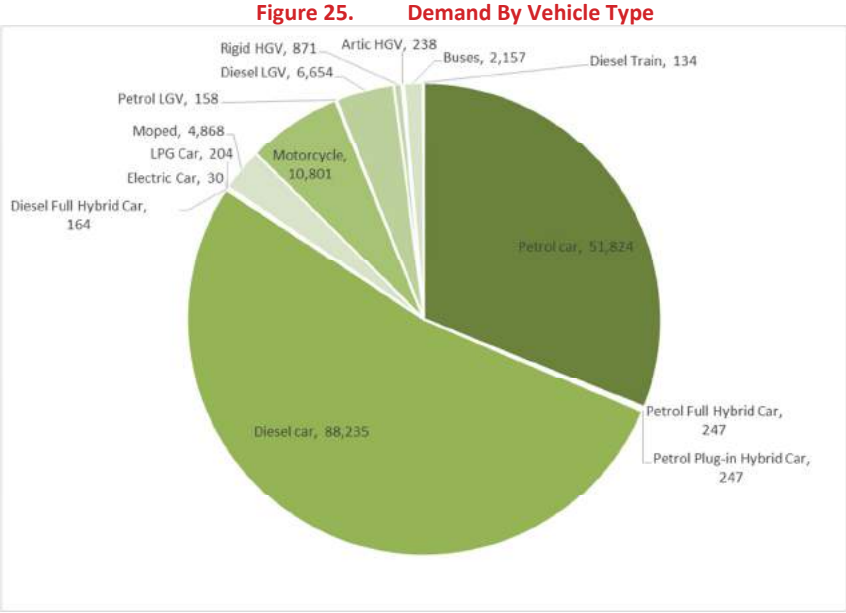
5.2.6 Table 16 shows the demand split into Vehicle Types and total vehicle kilometres. For the Private vehicles and Goods vehicles this reflects the Vehicle Splits input to the model. Public transport demand makes up 1% of the total demand, but less than 1% of vehicles.

Table 16. Demand By Vehicle Type

VEHICLE TYPE	PERSON DEMAND	VEHICLE DEMAND	% PERSON	% VEHICLES	VEHICLE KMS
Petrol car	51,824	39,092	31%	30%	493,200
Petrol Full Hybrid Car	247	187	0%	0%	2,355
Petrol Plug-in Hybrid Car	247	187	0%	0%	2,355
Diesel car	88,235	66,558	53%	52%	839,718
Diesel Full Hybrid Car	164	124	0%	0%	1,565
Electric Car	30	22	0%	0%	283
LPG Car	204	154	0%	0%	633
Moped	4,868	4,868	3%	4%	18,721
Motorcycle	10,801	10,801	6%	8%	41,538
Petrol LGV	158	129	0%	0%	988
Diesel LGV	6,654	5,427	4%	4%	41,505
Rigid HGV	871	871	1%	1%	6,660
Artic HGV	238	238	0%	0%	1,816
Buses	2,157	417	1%	0%	3,979
Diesel Train	134	68	0%	0%	2,659
Total	166,833	129,142	100%	100%	1,457,976

5.2.7 Figure 25 shows the vehicle type splits graphically.

Figure 25. Demand By Vehicle Type



5.2.8 Table 17 provides a comparison between the modelled vehicles and actual fleet figures for Evora. The figures were provided by Evora Municipality and cover the 2010 vehicle stock from ACAP.

5.2.9 The number of vehicles reported in Evora appears too high, with each person owning on average 1.26 cars each. The national figure is 0.43 cars per person. We would expect the Evora value to be slightly higher than this due to the rural nature of a large proportion of the region, compared to the bigger cities such as Lisbon and Porto, where there is better public transport provision.

5.2.10 Therefore we are happy with the modelled value of 0.68 cars per person, but welcome additional local information for improved comparison.

Table 17. Modelled and Actual Vehicle Comparison

VEHICLE TYPE	PORTUGAL (ACAP)	EVORA (ACAP)	MODELLED
Population	10,460,000	56,595	56,595
Cars	4,480,000	71,116	38,420
LGV	1,205,000	23,768	1,235
HGV	132,000	2,038	246
Bike	498,000	9,166	5,662
Total Vehicles	6,315,000	106,088	45,563
Cars per person	0.43	1.26	0.68
Bikes per person	0.05	0.16	0.10

5.2.11 Figure 26 to Figure 28 show the zone-zone movements for Private vehicles (Cars and motorbikes), Public Transport and Goods Vehicles.

5.2.12 The Private Vehicles demand is highest for zone 12 due to the high number of both origins and destinations in this zone. Zones with no Public Transport demand show the areas where no PT services can be accessed. The goods vehicle demand is focused around large areas of industrial and retail floorspace.

Figure 26. Highway Demand

	21	18	19	20	6	7	8	9	10	11	12	13	14	15	16	1	2	3	4	5	17	22		
All Purposes	Catedral de Evora	Jardim Publico de Evora	Aquaduct	Universidade de Evora	Bairro de Almeirim	Evora Retail Park	Aerodromo	Monte das Flores	Horta das Figueiras	Bairro Nossa sra do Carmo	Bairro De Santa Maria	Bairro dos Tres Bicos	Cemiterio de Evora	Nossa Sra da Saude	Bairro Frei Aleixo	Valverde	Sao Mancos	Nossa Sra de Machede	Azaruja	Canaviais	Bacelo	External	Total	Origin Splits
21 Catedral de Evora	280	11	5	18	27	122	17	0	27	259	205	31	9	124	44	0	0	0	1	15	15	45	1255	1%
18 Jardim Publico de Evora	13	2093	19	46	664	852	215	0	145	1283	994	126	45	174	434	0	0	0	4	37	70	271	7486	5%
19 Aquaduct	0	107	94	212	1369	1760	400	0	14	2089	574	576	175	405	1345	0	0	0	0	0	484	361	9966	6%
20 Universidade de Evora	0	5	2	57	817	1024	224	0	2	1018	203	47	19	108	501	0	0	0	0	0	42	153	4223	3%
6 Bairro de Almeirim	10	39	12	64	594	831	312	0	174	570	624	55	32	197	181	0	0	0	6	28	35	142	3903	2%
7 Evora Retail Park	1	3	1	5	28	41	15	0	19	28	59	4	2	13	13	0	0	0	1	2	2	9	247	0%
8 Aerodromo	7	20	7	29	111	149	136	0	86	102	185	16	10	72	63	0	0	0	5	14	9	38	1058	1%
9 Monte das Flores	12	47	15	57	183	431	94	0	202	548	1007	57	31	148	132	0	0	0	5	34	31	114	3147	2%
10 Horta das Figueiras	1	39	4	74	230	428	59	0	1304	929	139	126	71	177	189	0	0	0	0	2	96	146	4013	3%
11 Bairro Nossa sra do Carmo	11	47	14	58	204	301	101	0	249	482	987	66	21	232	115	0	0	0	5	31	31	111	3067	2%
12 Bairro De Santa Maria	45	187	62	248	1822	2747	614	0	530	2424	5941	505	187	542	1385	0	0	0	25	133	223	663	18282	12%
13 Bairro dos Tres Bicos	37	93	47	138	763	1062	286	0	301	1155	2783	292	59	420	714	0	0	0	18	133	91	316	8707	6%
14 Cemiterio de Evora	10	34	13	39	52	182	41	0	115	581	1155	69	132	142	79	0	0	0	4	41	17	102	2810	2%
15 Nossa Sra da Saude	178	317	170	768	1418	2411	944	0	1695	2661	4448	480	153	3210	1361	0	0	0	90	581	233	795	21912	14%
16 Bairro Frei Aleixo	49	136	61	214	312	506	172	0	407	455	1038	241	142	475	733	0	0	0	107	301	187	208	5746	4%
1 Valverde	0	42	9	68	1276	2759	447	0	11	2547	718	111	158	172	1057	0	0	0	0	0	91	356	9822	6%
2 Sao Mancos	100	265	109	373	757	1179	511	0	1030	878	1489	136	105	457	720	0	0	0	105	152	79	318	8762	6%
3 Nossa Sra de Machede	115	228	117	398	488	811	336	0	898	628	1602	148	84	602	750	0	0	0	272	212	78	292	8060	5%
4 Azaruja	0	17	4	26	857	1206	293	0	4	902	271	58	55	68	1041	0	0	0	0	0	50	183	5033	3%
5 Canaviais	37	85	44	141	626	1230	265	0	287	1335	1230	135	67	422	927	0	0	0	36	861	143	296	8167	5%
17 Bacelo	93	223	121	388	1048	1516	442	0	684	1732	3336	498	145	1292	1319	0	0	0	46	1510	520	561	15474	10%
22 External	38	152	35	129	513	811	223	0	308	851	1091	142	64	356	493	0	0	0	27	154	95	0	5481	3%
Total	1036	4191	966	3548	14157	22357	6147	0	8494	23457	30079	3918	1765	9806	13596	0	0	0	757	4242	2623	5481	156620	
Destination Splits	1%	3%	1%	2%	9%	14%	4%	0%	5%	15%	19%	3%	1%	6%	9%	0%	0%	0%	0%	3%	2%	3%		

Figure 27. Public Transport Demand

All Purposes	21 Catedral de Evora	18 Jardim Publico de Evora	19 Aquaduct	20 Universidade de Evora	6 Bairro de Almeirim	7 Evora Retail Park	8 Aerodromo	9 Monte das Flores	10 Horta das Figueiras	11 Bairro Nossa sra do Carmo	12 Bairro De Santa Maria	13 Bairro dos Tres Bicos	14 Ceniterio de Evora	15 Nossa Sra da Saude	16 Bairro Frei Aleixo	1 Valverde	2 Sao Mancos	3 Nossa Sra de Machede	4 Azaruja	5 Canaviais	17 Bacelo	22 External	Total	Origin Splits
21 Catedral de Evora	2	1	0	2	0	2	0	0	4	3	1	0	1	0	1	0	0	0	0	0	0	1	20	1%
18 Jardim Publico de Evora	3	13	1	7	9	9	0	0	25	22	6	1	4	1	11	0	0	0	0	0	1	4	117	6%
19 Aquaduct	0	2	3	6	26	25	0	0	0	28	6	7	12	3	29	0	0	0	0	0	3	6	155	8%
20 Universidade de Evora	0	0	0	1	14	14	0	0	0	13	2	1	2	1	16	0	0	0	0	0	0	2	66	3%
6 Bairro de Almeirim	1	2	1	1	10	11	0	0	10	11	5	1	1	1	3	0	0	0	0	0	1	2	61	3%
7 Evora Retail Park	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	4	0%
8 Aerodromo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
9 Monte das Flores	1	3	1	3	2	4	0	0	12	13	3	1	1	1	2	0	0	0	0	0	0	2	49	3%
10 Horta das Figueiras	1	1	0	4	5	8	0	0	16	11	3	2	3	2	3	0	0	0	0	0	1	2	63	3%
11 Bairro Nossa sra do Carmo	1	2	1	3	4	5	0	0	13	6	5	1	1	1	2	0	0	0	0	0	0	2	48	2%
12 Bairro De Santa Maria	4	10	5	13	35	43	0	0	41	41	37	5	6	8	21	0	0	0	0	3	3	10	285	15%
13 Bairro dos Tres Bicos	2	5	3	7	14	17	0	0	25	20	16	3	3	3	11	0	0	0	0	1	1	5	136	7%
14 Ceniterio de Evora	1	1	2	4	1	4	0	0	15	7	2	1	3	1	2	0	0	0	0	0	0	2	44	2%
15 Nossa Sra da Saude	6	17	7	26	22	36	0	0	73	34	52	5	7	15	24	0	0	0	0	2	2	12	342	18%
16 Bairro Frei Aleixo	2	3	2	6	5	8	0	0	18	7	10	4	4	3	11	0	0	0	0	1	2	3	90	5%
1 Valverde	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
2 Sao Mancos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
3 Nossa Sra de Machede	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
4 Azaruja	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
5 Canaviais	2	3	2	6	12	21	0	0	17	22	16	2	3	2	12	0	0	0	0	2	1	5	127	7%
17 Bacelo	5	7	6	16	22	27	0	0	49	26	30	6	7	5	18	0	0	0	0	4	4	9	241	13%
22 External	1	3	1	4	7	9	0	0	12	10	7	1	2	2	6	0	0	0	0	1	1	0	67	3%
Total	33	74	36	110	189	243	0	0	332	275	201	38	58	49	173	0	0	0	0	16	20	67	1914	
Destination Splits	2%	4%	2%	6%	10%	13%	0%	0%	17%	14%	10%	2%	3%	3%	9%	0%	0%	0%	0%	1%	1%	3%		

Figure 28. Goods Vehicle Demand

All Purposes	21 Catedral de Evora	18 Jardim Publico de Evora	19 Aquaduct	20 Universidade de Evora	6 Bairro de Almeirim	7 Evora Retail Park	8 Aerodromo	9 Monte das Flores	10 Horta das Figueiras	11 Bairro Nossa sra do Carmo	12 Bairro De Santa Maria	13 Bairro dos Tres Bicos	14 Ceniterio de Evora	15 Nossa Sra da Saude	16 Bairro Frei Aleixo	1 Valverde	2 Sao Mancos	3 Nossa Sra de Machede	4 Azaruja	5 Canaviais	17 Bacelo	22 External	Total	Origin Splits
21 Catedral de Evora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
18 Jardim Publico de Evora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
19 Aquaduct	0	0	0	0	0	1	0	0	0	2	2	0	1	1	0	0	0	0	0	0	0	0	8	0%
20 Universidade de Evora	0	0	0	1	0	3	0	0	0	6	2	0	1	4	1	0	0	0	0	0	0	1	19	0%
6 Bairro de Almeirim	0	0	0	0	264	317	18	0	0	145	6	0	0	0	7	0	0	0	0	0	0	28	785	10%
7 Evora Retail Park	0	0	1	3	406	1812	56	0	0	878	58	0	6	10	37	0	0	0	0	0	0	123	3390	43%
8 Aerodromo	0	0	0	1	61	135	25	0	0	77	12	0	2	4	10	0	0	0	0	0	0	12	340	4%
9 Monte das Flores	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
10 Horta das Figueiras	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
11 Bairro Nossa sra do Carmo	0	0	1	2	86	402	11	0	0	1242	25	0	6	5	11	0	0	0	0	0	0	67	1858	23%
12 Bairro De Santa Maria	0	0	2	3	22	106	8	0	0	117	81	0	14	10	14	0	0	0	0	0	0	14	392	5%
13 Bairro dos Tres Bicos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
14 Ceniterio de Evora	0	0	1	1	0	4	1	0	0	15	9	0	8	2	1	0	0	0	0	0	0	2	44	1%
15 Nossa Sra da Saude	0	0	1	5	0	15	3	0	0	23	12	0	4	12	4	0	0	0	0	0	0	3	82	1%
16 Bairro Frei Aleixo	0	0	1	3	74	221	23	0	0	184	39	0	5	9	143	0	0	0	0	0	0	26	728	9%
1 Valverde	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
2 Sao Mancos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
3 Nossa Sra de Machede	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
4 Azaruja	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
5 Canaviais	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
17 Bacelo	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0%
22 External	0	0	0	1	34	114	6	0	0	101	9	0	2	2	9	0	0	0	0	0	0	0	277	3%
Total	0	0	7	19	947	3130	152	0	0	2790	256	0	49	59	235	0	0	0	0	0	0	277	7922	
Destination Splits	0%	0%	0%	1%	49%	164%	8%	0%	0%	146%	13%	0%	3%	3%	12%	0%	0%	0%	0%	0%	0%	14%		

5.2.13 Table 18 shows the Public Transport boardings by bus and train. On average there is an average occupancy of 4.8 people per vehicle. This is very low, but is not unexpected given the low PT mode share of 1%.

5.2.14 (Note: the train demand includes only demand going to/from Evora and not demand passing through).

Table 18. PT Demand by Route

ROUTE NO	BOARDINGS	DAILY SERVICES	AVERAGE OCCUPANCY
Buses	2,158	410	5.3
Train	134	68	2.0
Total	**2,292**	**478**	**4.8**
Demand	1,914		
Average Boardings Per Journey	1.20		

5.3 Energy Outputs

5.3.1 This section covers the Energy Consumption/Usage within Evora. This includes

- Total Energy per person, trip and vehicle type;
- Energy by Origin zone; and
- Zone-zone Energy flows.

5.3.2 Table 19 presents a summary of the total energy used by transport within Evora. The total daily value across all modes, vehicle types, purposes and zones is **3,900,627 MJ**, which is around 69MJ per person per day.

Table 19. Energy Usage Summary

NO	TOTAL	CARS	BIKES	GOODS	BUSES	TRAINS
Total Energy (MJ)	3,900,627	3,421,265	102,025	269,579	59,214	48,544
Population	56,595					
Energy Per Person (MJ)	68.9	60.5	1.8	4.8	1.0	0.9
Demand (Persons)	166,833	140,952	15,668	7,922	2,157	134
Energy Per Trip (MJ)	23.4	24.3	6.5	34.0	27.5	362.3
Trips Per Person	2.9	2.5	0.3	0.1	0.0	0.0
Actual Vehicles	46,048	38,421	5,662	1,481	417	68
Energy Per Vehicle (MJ)	84.7	89.0	18.0	182.0	142.0	713.9
Vehicles Per Person	0.81	0.68	0.10	0.03	0.01	0.001

Note 1: Energy per Person for Goods demand isn't really meaningful as the demand is not based on residential locations. An increase in population would not necessarily lead to an increase in goods demand in the same way it would with car demand.

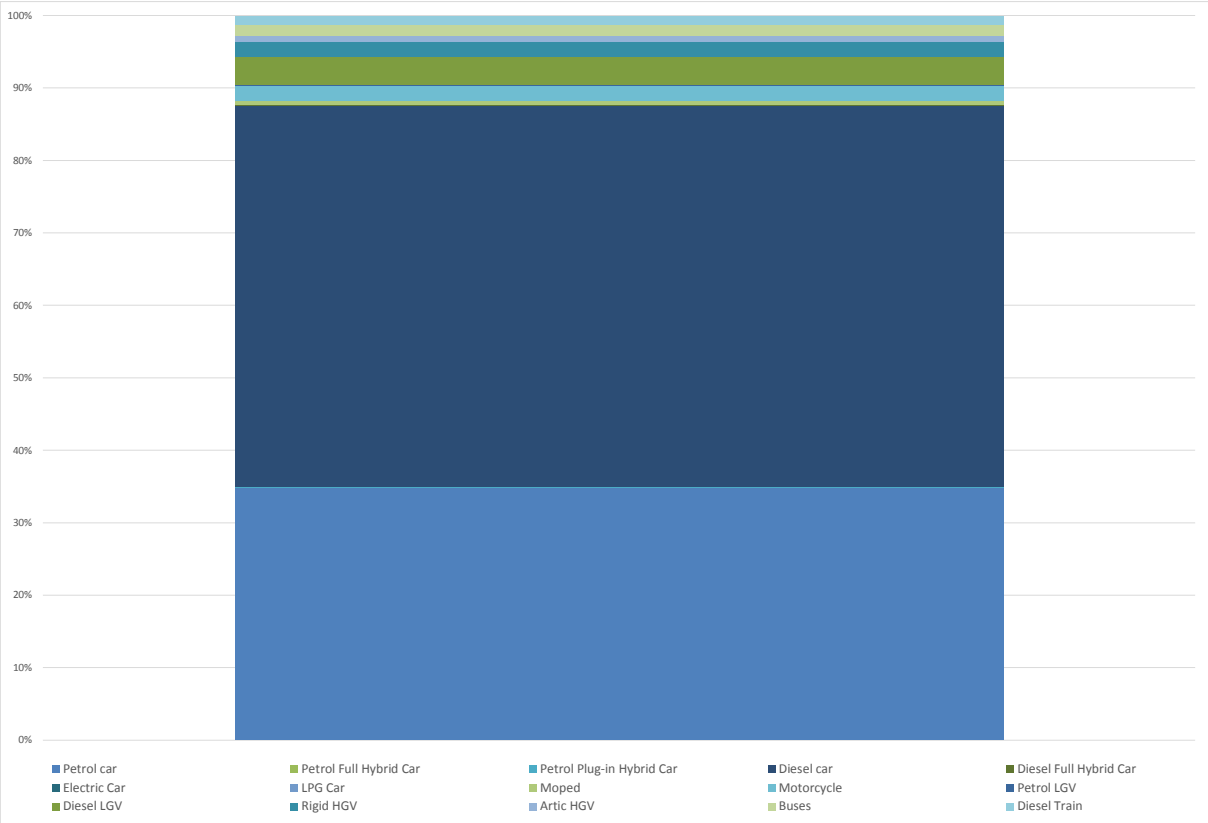
5.3.3 Table 20 shows the Energy figures split into Vehicles Types. Cars represent the large share, roughly in line with the proportion of petrol and diesel vehicles. Unsurprisingly Goods demand use a high amount of energy compared to the number of vehicles – consuming 7% of the total energy from only 3% of the vehicles. Diesel trains also use a lot of energy per vehicle with 1% of the usage from 0.1% of the total vehicles.

5.3.4 Figure 29 shows the Energy Usage split by Vehicle Type

Table 20. Energy Consumption (MJ) by Vehicle Type

VEHICLE TYPE	TOTAL ENERGY	% ENERGY	VEHICLES	ENERGY PER VEHICLE
Petrol car	1,355,755	35%	14,126	96
Petrol Full Hybrid Car	3,758	0%	67	56
Petrol Plug-in Hybrid Car	3,618	0%	67	54
Diesel car	2,053,732	53%	24,051	85
Diesel Full Hybrid Car	2,229	0%	45	50
Electric Car	109	0%	8	13
LPG Car	2,065	0%	55	37
Moped	18,948	0%	1,759	11
Motorcycle	83,076	2%	3,903	21
Petrol LGV	4,047	0%	29	141
Diesel LGV	149,594	4%	1,206	124
Rigid HGV	78,938	2%	194	408
Artic HGV	37,001	1%	53	701
Buses	59,214	2%	417	142
Diesel Train	48,544	1%	68	714
Total	3,900,627	100%	46,048	85
Cars	3,421,265	88%	38,420	89
Bikes	102,025	3%	5,662	18
Goods	269,579	7%	1,481	182
Buses	59,214	2%	417	142
Trains	48,544	1%	68	714

Figure 29. Energy Usage By Vehicle Type



5.3.5 Table 21 shows the Energy Usage split into zones, based on the residential origin of the trip. Figure 30 shows the total energy per zone and Figure 31 shows the energy per person. There are a number effects present here;

- Zones to the south of the city have relatively low populations. They are also close to the major attractors in zones 7, 10 and 11, meaning they have less distance to travel and therefore using less energy.
- Zones to the north of the city have larger populations and therefore generate higher total energy usage. On top of this there are large number of cross-city trips to get to the main attractors on the south side of the city.
- The outer zones have high energy usage due to the large distances required to travel to the city centre. In addition there is no public transport available.

Table 21. Energy Per Zone – Private Vehicles

NO	ZONE NAME	AREA TYPE	POP	DEMAND	ENERGY (MJ)	ENERGY/ PERSON	ENERGY /TRIP
21	Catedral de Evora	1	233	900	10,332	44.4	11.5
18	Jardim Publico de Evora	2	1,312	5,781	67,329	51.3	11.6
19	Aquaduct	2	2,262	8,574	121,947	53.9	14.2
20	Universidade de Evora	2	934	3,714	51,052	54.6	13.7
6	Bairro de Almeirim	3	1,461	3,081	38,461	26.3	12.5
7	Evora Retail Park	3	76	190	2,858	37.7	15.0
8	Aerodromo	3	388	808	16,259	41.9	20.1
9	Monte das Flores	3	1,342	2,344	35,055	26.1	15.0
10	Horta das Figueiras	3	3,465	3,066	31,153	9.0	10.2
11	Bairro Nossa sra do Carmo	3	1,160	2,287	26,013	22.4	11.4
12	Bairro De Santa Maria	3	8,656	14,345	232,910	26.9	16.2
13	Bairro dos Tres Bicos	3	4,637	6,724	110,464	23.8	16.4
14	Ceniterio de Evora	3	1,187	1,999	22,883	19.3	11.4
15	Nossa Sra da Saude	3	8,589	16,267	268,799	31.3	16.5
16	Bairro Frei Aleixo	3	2,113	4,314	107,120	50.7	24.8
1	Valverde	4	2,719	8,265	442,407	162.7	53.5
2	Sao Mancos	4	2,017	6,689	473,045	234.5	70.7
3	Nossa Sra de Machede	4	1,917	5,937	271,624	141.7	45.8
4	Azaruja	4	1,151	4,427	215,100	186.9	48.6
5	Canaviais	4	3,442	6,313	143,951	41.8	22.8
17	Bacelo	4	7,533	11,697	212,298	28.2	18.1
22	External	5		4,269	622,230		145.7
	Total (inc External)			**121,992**	**3,523,290**	**-**	**28.9**
	Total (exl External)		**56,595**	**117,723**	**2,901,060**	**51.3**	**24.6**

Figure 30. Total Energy (MJ) Per Origin Zone

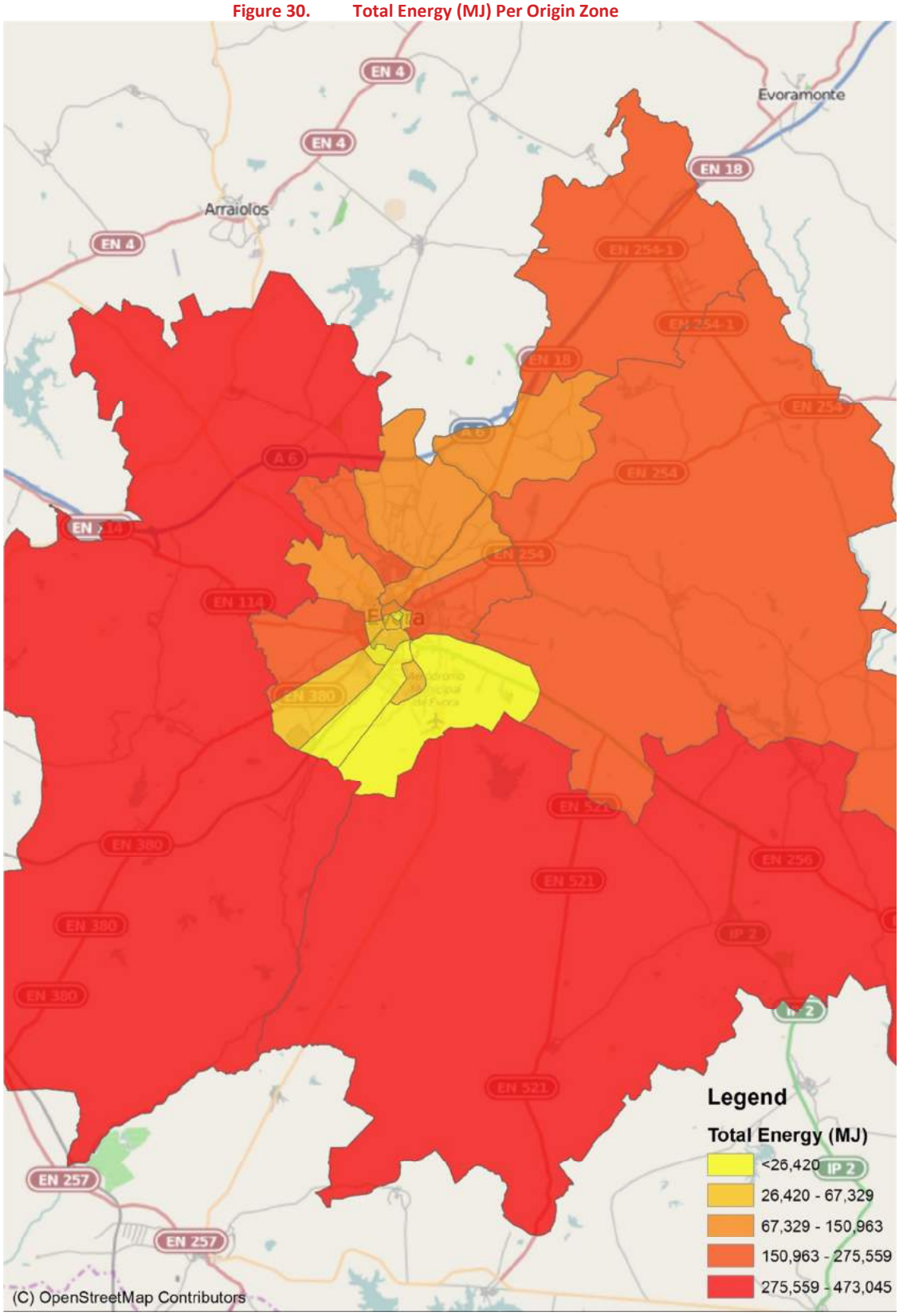
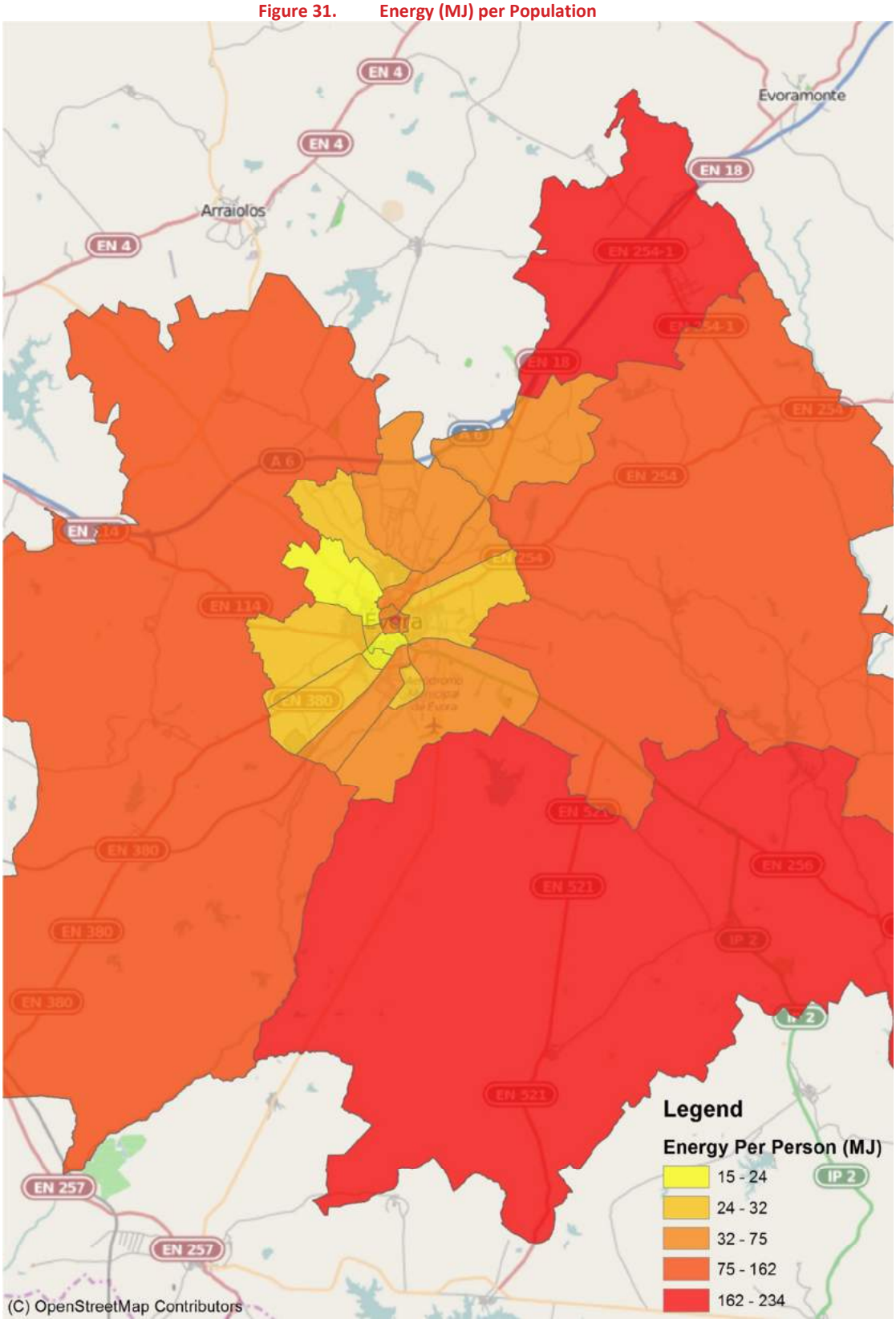


Figure 31. Energy (MJ) per Population



5.3.6 Table 22 to Table 24 show the zone-zone energy usage flows. The highway and goods matrices are similar to the demand matrices.

5.3.7 However, the Public Transport energy is calculated on the basis of the actual vehicles serving the routes, rather than the demand. They are then allocated based on the start and end zone of each service. Hence, the majority of the PT energy is to/from zones 14 and 21.

Table 22. Zonal Energy Usage – Private Vehicles

Private Vehicles	21 Catedral de Evora	18 Jardim Publico de Evora	19 Aquaduct	20 Universidade de Evora	6 Bairro de Almeirim	7 Evora Retail Park	8 Aerodromo	9 Monte das Flores	10 Horta das Figueiras	11 Bairro Nossa sra do Carmo	12 Bairro De Santa Maria	13 Bairro dos Tres Bicos	14 Ceniterio de Evora	15 Nossa Sra da Saude	16 Bairro Frei Aleixo	1 Valverde	2 Sao Mancos	3 Nossa Sra de Machede	4 Azaruja	5 Canaviais	17 Bacelo	22 External	Total	Origin Splits
21 Catedral de Evora	420	24	7	44	255	1,132	196	-	106	1,249	1,072	118	29	438	472	-	-	-	35	125	77	4,533	10,332	0%
18 Jardim Publico de Evora	27	3,362	36	222	5,572	7,948	2,543	-	394	4,251	4,969	614	116	1,036	5,905	-	-	-	115	340	475	29,406	67,329	2%
19 Aquaduct	-	241	186	753	14,003	19,635	5,666	-	65	10,449	3,712	2,083	514	2,098	15,950	-	-	-	-	-	2,232	44,360	121,947	3%
20 Universidade de Evora	-	28	6	139	6,245	8,827	2,600	-	9	4,931	1,772	258	93	330	6,240	-	-	-	-	-	255	19,320	51,052	1%
6 Bairro de Almeirim	66	240	83	368	1,757	3,822	1,879	-	818	2,791	4,545	526	234	1,378	3,206	-	-	-	168	359	401	15,820	38,461	1%
7 Evora Retail Park	8	25	9	38	168	254	140	-	103	164	451	41	19	112	250	-	-	-	19	36	30	990	2,858	0%
8 Aerodromo	67	197	77	287	1,065	1,777	1,111	-	862	1,188	2,276	231	119	727	1,447	-	-	-	152	252	155	4,269	16,259	0%
9 Monte das Flores	76	246	95	403	1,775	3,705	1,216	-	1,004	3,010	6,122	497	185	1,236	2,460	-	-	-	169	430	334	12,094	35,055	1%
10 Horta das Figueiras	2	126	18	299	1,499	2,487	686	-	2,014	1,930	872	788	267	967	2,798	-	-	-	7	18	760	15,615	31,153	1%
11 Bairro Nossa sra do Carmo	47	127	55	231	1,146	1,542	926	-	439	853	4,898	381	78	1,210	1,767	-	-	-	138	344	240	11,591	26,013	1%
12 Bairro De Santa Maria	271	1,170	371	2,091	22,078	31,343	10,157	-	3,538	19,388	29,731	3,235	1,123	4,961	24,124	-	-	-	727	1,649	2,286	74,668	232,910	7%
13 Bairro dos Tres Bicos	153	490	180	812	10,362	15,196	4,747	-	1,923	9,086	15,197	1,337	315	2,824	10,461	-	-	-	486	1,365	720	34,811	110,464	3%
14 Ceniterio de Evora	29	77	33	176	480	1,670	447	-	380	2,099	4,627	276	284	750	940	-	-	-	111	363	111	10,032	22,883	1%
15 Nossa Sra da Saude	788	2,137	915	2,871	16,289	28,773	11,301	-	10,162	20,755	38,251	3,575	1,124	16,694	19,894	-	-	-	2,435	6,318	2,034	84,482	268,799	8%
16 Bairro Frei Aleixo	501	1,686	658	2,500	6,993	11,374	3,995	-	5,629	7,897	14,276	3,315	1,892	6,057	8,936	-	-	-	2,387	3,692	2,617	22,719	107,120	3%
1 Valverde	-	1,546	363	2,821	58,257	115,826	23,173	-	444	89,826	26,333	4,333	5,361	6,766	55,211	-	-	-	-	-	3,676	48,473	442,407	13%
2 Sao Mancos	4,001	10,724	4,470	15,137	46,445	70,785	27,142	-	45,922	47,318	66,673	6,615	5,043	18,972	46,114	-	-	-	6,979	7,768	4,163	38,773	473,045	13%
3 Nossa Sra de Machede	2,569	5,726	2,751	8,978	19,674	32,044	12,666	-	25,284	22,053	44,184	4,177	2,453	14,359	22,715	-	-	-	10,264	6,567	2,416	32,744	271,624	8%
4 Azaruja	-	535	120	838	38,381	54,042	14,213	-	165	34,238	10,502	1,834	1,674	2,134	30,830	-	-	-	-	-	1,595	23,998	215,100	6%
5 Canaviais	309	859	377	1,354	12,456	24,129	5,878	-	3,306	19,190	15,128	1,506	731	4,471	13,035	-	-	-	963	6,514	1,208	32,537	143,951	4%
17 Bacelo	464	1,510	567	2,496	16,425	24,634	7,972	-	5,389	16,547	28,209	3,659	1,032	9,276	18,608	-	-	-	1,267	10,912	2,914	60,416	212,298	6%
22 External	3,316	14,073	3,279	12,770	72,030	109,445	28,994	-	27,339	100,981	104,036	14,893	6,834	34,059	61,705	-	-	-	2,780	15,247	10,447	-	622,230	18%
Total	13,114	45,149	14,655	55,626	353,354	570,391	167,644	-	135,295	420,196	427,835	54,291	29,521	130,855	353,067	-	-	-	29,200	62,300	39,146	621,652	3,523,290	
Destination Splits	0%	1%	0%	2%	10%	16%	5%	0%	4%	12%	12%	2%	1%	4%	10%	0%	0%	0%	1%	2%	1%	18%		

Table 23. Zonal Energy Usage – Goods Vehicles

Goods Demand	21 Catedral de Evora	18 Jardim Publico de Evora	19 Aquaduct	20 Universidade de Evora	6 Bairro de Almeirim	7 Evora Retail Park	8 Aerodromo	9 Monte das Flores	10 Horta das Figueiras	11 Bairro Nossa sra do Carmo	12 Bairro De Santa Maria	13 Bairro dos Tres Bicos	14 Ceniterio de Evora	15 Nossa Sra da Saude	16 Bairro Frei Aleixo	1 Valverde	2 Sao Mancos	3 Nossa Sra de Machede	4 Azaruja	5 Canaviais	17 Bacelo	22 External	Total	Origin Splits
21 Catedral de Evora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
18 Jardim Publico de Evora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
19 Aquaduct	-	-	2	3	-	21	4	-	-	28	25	-	8	11	8	-	-	-	-	-	-	76	186	0%
20 Universidade de Evora	-	-	3	7	-	53	10	-	-	64	40	-	11	33	16	-	-	-	-	-	-	175	412	0%
6 Bairro de Almeirim	-	-	-	-	1,698	3,404	295	-	-	1,821	148	-	-	-	305	-	-	-	-	-	-	7,952	15,622	6%
7 Evora Retail Park	-	-	21	61	5,380	24,513	1,361	-	-	12,329	1,410	-	131	240	1,752	-	-	-	-	-	-	34,032	81,231	30%
8 Aerodromo	-	-	11	30	1,283	3,603	558	-	-	2,181	458	-	66	129	573	-	-	-	-	-	-	3,524	12,415	5%
9 Monte das Flores	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
10 Horta das Figueiras	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
11 Bairro Nossa sra do Carmo	-	-	8	21	1,052	4,518	265	-	-	5,414	392	-	57	76	398	-	-	-	-	-	-	18,342	30,543	11%
12 Bairro De Santa Maria	-	-	33	63	582	2,640	303	-	-	2,232	1,215	-	213	252	550	-	-	-	-	-	-	3,822	11,904	4%
13 Bairro dos Tres Bicos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
14 Ceniterio de Evora	-	-	5	9	-	89	17	-	-	140	115	-	47	34	27	-	-	-	-	-	-	397	880	0%
15 Nossa Sra da Saude	-	-	17	55	-	383	83	-	-	421	297	-	80	188	123	-	-	-	-	-	-	766	2,411	1%
16 Bairro Frei Aleixo	-	-	36	82	3,611	11,257	1,312	-	-	7,985	1,662	-	181	334	4,489	-	-	-	-	-	-	7,535	38,484	14%
1 Valverde	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
2 Sao Mancos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
3 Nossa Sra de Machede	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
4 Azaruja	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
5 Canaviais	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
17 Bacelo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
22 External	-	-	67	174	9,544	30,984	1,536	-	-	27,403	2,421	-	443	548	2,370	-	-	-	-	-	-	-	75,491	28%
Total	-	-	202	504	23,151	81,464	5,743	-	-	60,018	8,183	-	1,237	1,844	10,612	-	-	-	-	-	-	76,620	269,579	
Destination Splits	0%	0%	0%	0%	9%	30%	2%	0%	0%	22%	3%	0%	0%	1%	4%	0%	0%	0%	0%	0%	0%	28%		

Table 24. Zonal Energy Usage – Public Transport

All PT	21 Catedral de Evora	18 Jardim Publico de Evora	19 Aquaduct	20 Universidade de Evora	6 Bairro de Almeirim	7 Evora Retail Park	8 Aerodromo	9 Monte das Flores	10 Horta das Figueiras	11 Bairro Nossa sra do Carmo	12 Bairro De Santa Maria	13 Bairro dos Tres Bicos	14 Ceniterio de Evora	15 Nossa Sra da Saude	16 Bairro Frei Aleixo	1 Valverde	2 Sao Mancos	3 Nossa Sra de Machede	4 Azaruja	5 Canaviais	17 Bacelo	22 External	Total	Origin Splits
21 Catedral de Evora	12,246	-	-	-	-	-	-	1,293	-	-	-	-	-	-	-	-	-	-	-	1,006	1,544	-	16,088	15%
18 Jardim Publico de Evora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
19 Aquaduct	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
20 Universidade de Evora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
6 Bairro de Almeirim	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,528	2,203	-	4,731	4%
7 Evora Retail Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,869	-	-	2,869	3%
8 Aerodromo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
9 Monte das Flores	2,432	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,432	2%
10 Horta das Figueiras	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24,272	24,272	23%
11 Bairro Nossa sra do Carmo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
12 Bairro De Santa Maria	-	-	-	-	-	-	-	-	-	-	2,253	-	-	-	-	-	-	-	-	-	-	-	2,253	2%
13 Bairro dos Tres Bicos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
14 Ceniterio de Evora	-	-	-	-	-	-	-	-	-	-	-	-	13,148	-	-	-	-	-	-	-	-	-	13,148	12%
15 Nossa Sra da Saude	-	-	-	-	-	-	-	-	-	-	-	-	-	6,760	-	-	-	-	-	-	-	-	6,760	6%
16 Bairro Frei Aleixo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
1 Valverde	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
2 Sao Mancos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
3 Nossa Sra de Machede	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
4 Azaruja	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
5 Canaviais	1,415	-	-	-	2,528	3,069	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,012	7%
17 Bacelo	1,544	-	-	-	2,376	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,921	4%
22 External	-	-	-	-	-	-	-	-	24,272	-	-	-	-	-	-	-	-	-	-	-	-	-	24,272	23%
Total	17,637	-	-	-	4,905	3,069	-	1,293	24,272	-	2,253	-	13,148	6,760	-	-	-	-	-	6,403	3,747	24,272	107,758	
Destination Splits	16%	0%	0%	0%	5%	3%	0%	1%	23%	0%	2%	0%	12%	6%	0%	0%	0%	0%	0%	6%	3%	23%		

5.3.8 Table 25 shows the energy usage for buses and trains within Evora, including energy per passenger and per vehicle km.

Table 25. PT Energy Usage By Vehicle Type

ROUTE NO	TOTAL ENERGY	SERVICES	ROUTE LENGTH (KM)	VEHICLE KMS	ENERGY/ VEHKMS	ENERGY/ PASS
Buses	59,214	410	137.7	3,979	14.88	27.44
Train	48,544	68	39.1	2,659	18.26	362.27
Total	107,758	478	176.8	6,637	16.23	47.01

5.4 Emissions Outputs

5.4.1 This section of the report looks at other emissions calculated by the model. These include

- Nitrous Oxides;
- Particulate Matter (PM10s);
- Hydro Carbons;
- Carbon Monoxide; and
- Carbon Dioxide.

5.4.2 Figure 32 shows the Carbon Dioxide Emissions split into Vehicle Type. These splits are very similar to the Energy Usage splits.

5.4.3 Figure 33 shows the Vehicle Type splits for the other Emissions types. It can be seen that the splits here are very different to the Carbon Dioxide splits. Mopeds and Motorbikes are more responsible for Hydro-Carbons, PM10s and Carbon Monoxide, with diesel cars contributing substantially to PM10 emissions.

Figure 32. Carbon Dioxide Emissions By Vehicle Type

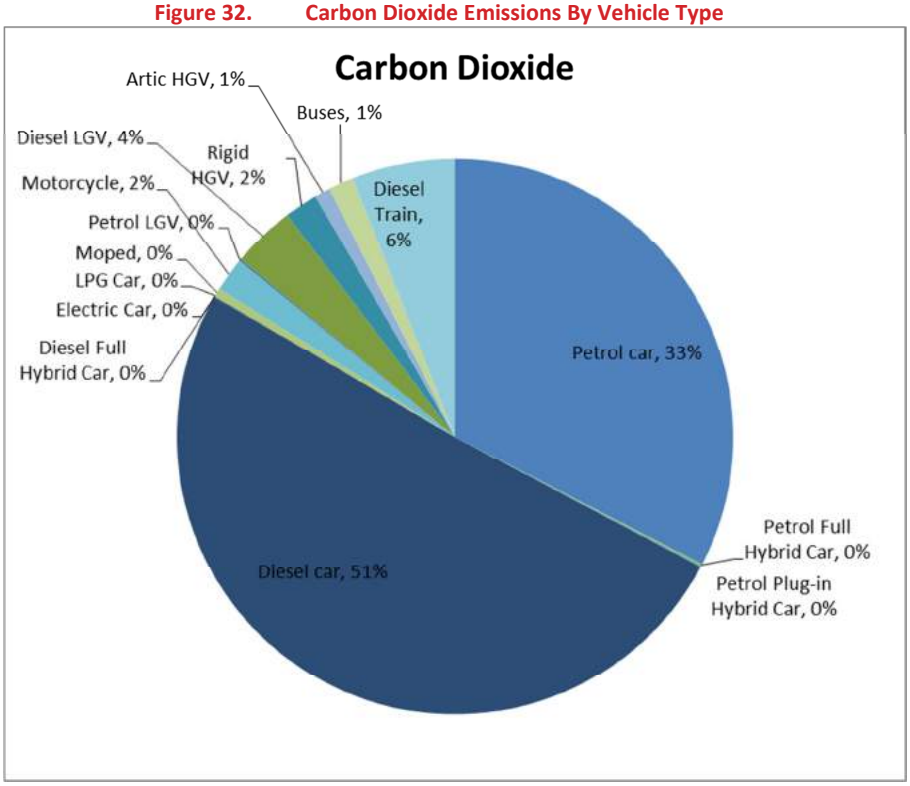


Figure 33. Emissions by Vehicle Type

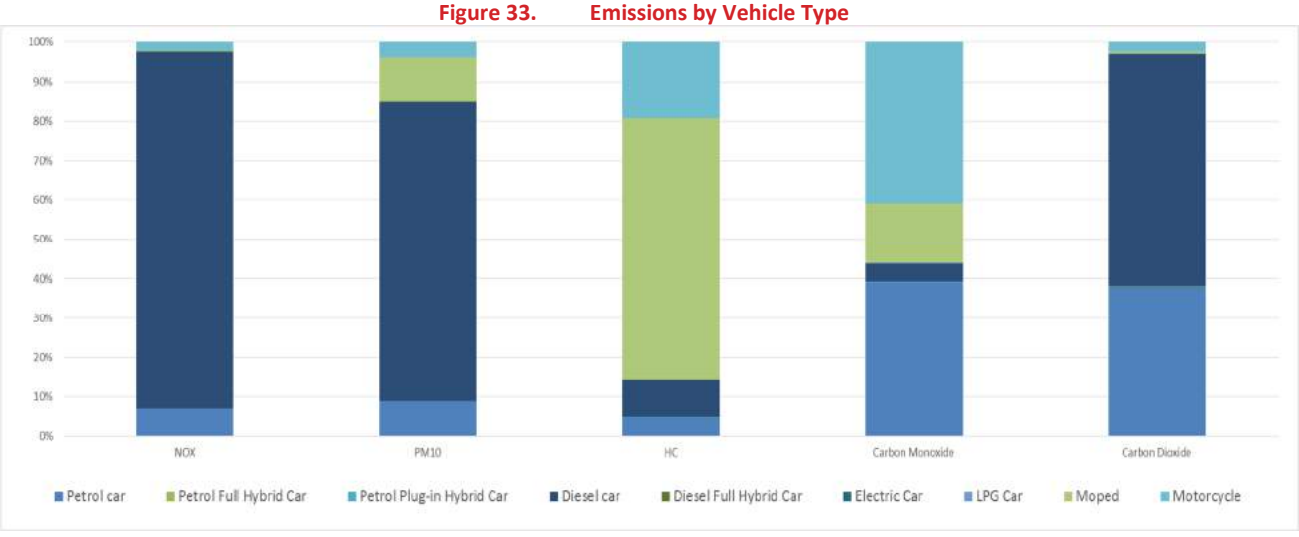


Table 26. Emissions By Vehicle Type

ROUTE NO	NOX	PM10	HCS	CO	CO2
Petrol car	28,757	1,700	9,519	397,188	99,701,203
Petrol Full Hybrid Car	78	8	23	1,218	276,335
Petrol Plug-in Hybrid Car	53	5	22	1,157	266,043
Diesel car	372,196	14,633	19,891	46,510	154,911,079
Diesel Full Hybrid Car	452	15	21	43	168,118
Electric Car	-	-	-	-	-
LPG Car	159	2	33	70	129,153
Moped	561	2,190	135,973	154,196	1,393,439
Motorcycle	8,793	726	39,255	416,296	6,109,370
Petrol LGV	87	2	47	2,914	297,581
Diesel LGV	22,530	1,094	1,869	9,616	11,283,743
Rigid HGV	25,483	390	729	4,301	5,954,238
Artic HGV	12,164	171	294	1,212	2,790,914
Buses	22,899	336	741	3,228	4,466,424
Diesel Train	-	-	-	-	18,353,696
Total	494,212	21,272	208,415	1,037,949	306,101,338
Cars	401,696	16,363	29,508	446,187	255,451,932
Bikes	9,353	2,917	175,228	570,492	7,502,809
Goods	60,264	1,657	2,939	18,042	20,326,476
Buses	22,899	336	741	3,228	4,466,424
Trains	-	-	-	-	18,353,696

WP3 – Transport and Mobility Analysis

D.3.4. Transport Base Year Report Cesena

October 2015

314164 (ENER/FP7/314164)

Project acronym:

InSMART

Project full title:

Integrative Smart City Planning

Coordination and support action (Coordinating Action)

FP7-ENERGY-SMARTICITIES-2012

Start date of project: 2013-12-01

Duration: 3 years

Deliverable D3.4

Transport Base Year Report Cesena

Work Package 3. Transport and Mobility Analysis

October 2015

Project co-funded by the European Commission within the Seventh Framework Programme		
Dissemination Level		
PU	Public	PU
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Executive Summary	
This report presents the results of the Baseline Scenario of the transport model that has been developed in the framework of the INSMART project for the city of Cesena.	
Keywords	Transport scenarios




BASE YEAR REPORT - CESENA

INSMART – INTEGRATIVE SMART CITY PLANNING

BASE YEAR REPORT - CESENA

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1. INTRODUCTION

1.1 Project Overview

1.1.1 InSmart is a three year, European funded project which involves four European Cities working in partnership towards a sustainable energy future. The primary objective of the project is to develop sustainable energy action plans for each partner city.

1.1.2 The four cities are;

- Cesena, Italy;
- Evora, Portugal;
- Nottingham, UK; and
- Trikala, Greece.

1.1.3 A mix of sustainable energy measures to improve the energy efficiency of each city will be identified through the use of a variety of tools and approaches. This will cover a wide range of sectors from the residential and transport sectors, to street lighting and waste collection.

1.1.4 SYSTRA's role within the project is to identify, test and report on a series of land use and transport based strategies aimed at reducing the transport-related energy usage and carbon generation of each city.

1.1.5 The initial task is to calculate the current energy usage and carbon emissions generated by each city. The impact of the forecast strategies can then be obtained by a comparison with the base figures.

1.2 Cesena

1.2.1 This report covers the city of Cesena in the Italian region of Emilia-Romagna.

1.2.2 The city has been split into 15 zones, as shown in Figure 1. In addition the model has a 16th zone covering the area external to the 15 internal zones – allowing for travel to and from the city.

1.2.3 The city has also been split into 5 Area Types representing different areas of the city. These are;

- City Centre;
- Edge of City Centre;
- Sub0Urban areas;
- Rural/Outside City; and
- External

1.2.4 Some inputs, such as vehicle speeds, are at this more aggregate level of detail. The Area Type allocation for the internal zones is shown in Figure 2.

1.3 Report Structure

1.3.1 The report is split into four sections;

- Executive Summary/Conclusions – the key aspects of the Base Year model outputs;
- Inputs – covering all the city-specific inputs;
- Calibration – details of model calibration to observed mode share and trip length information; and
- Outputs – details of demand movements, energy consumption and emissions.

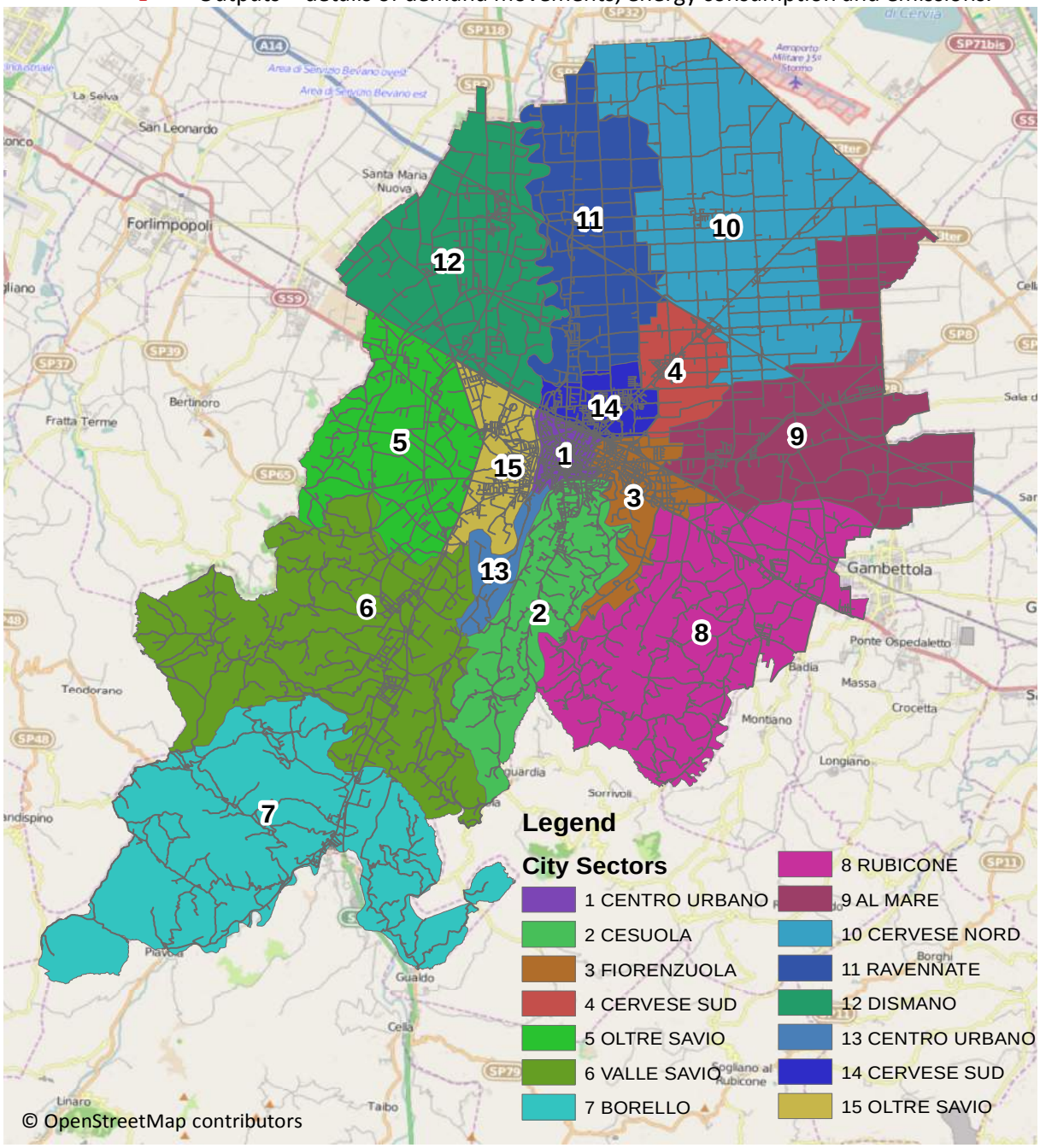

Figure 1. Cesena Zoning System

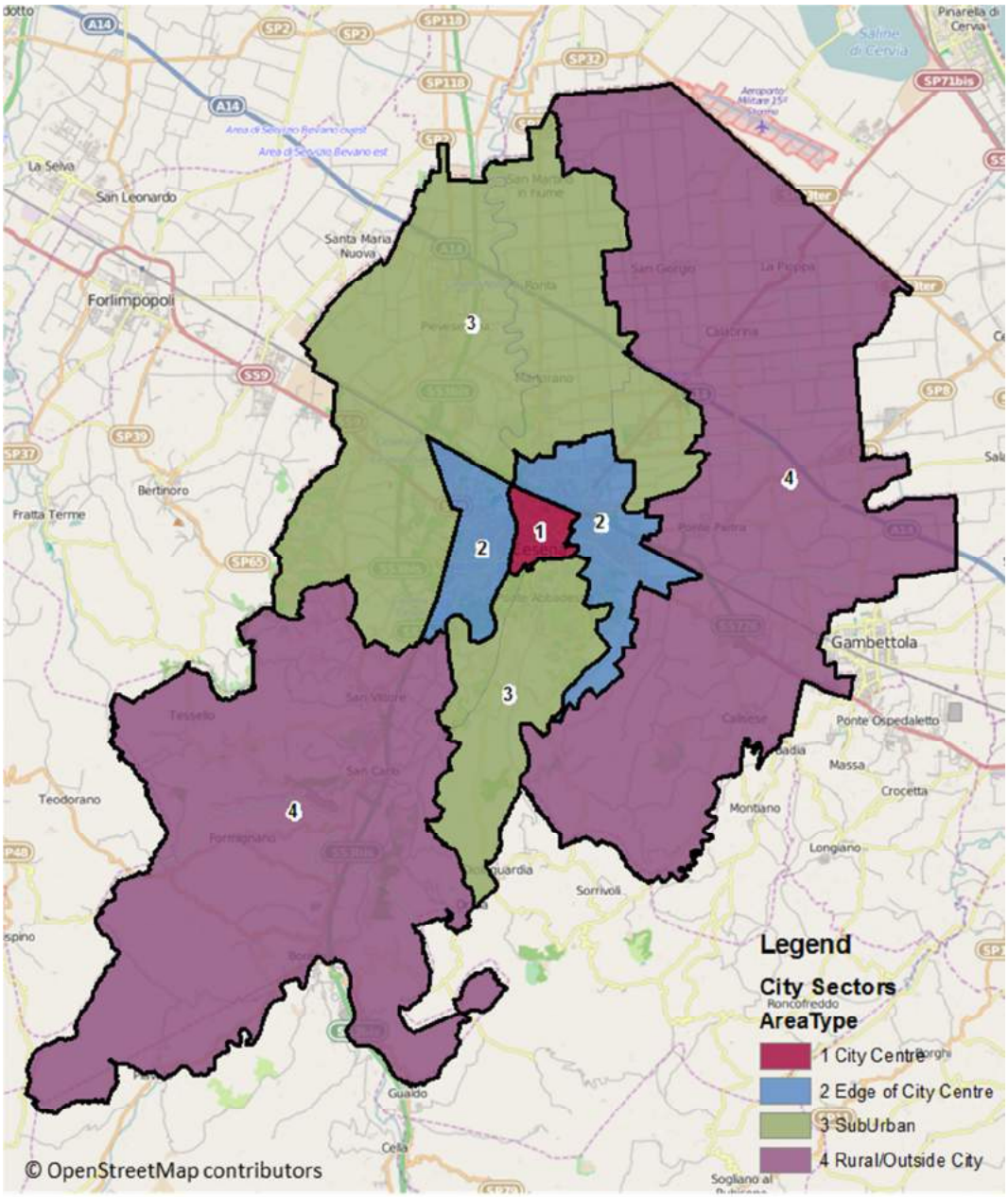

Figure 2. Cesena Area Types

2. EXECUTIVE SUMMARY/CONCLUSIONS

2.1 Introduction

2.1.1 This section of the report aims to summarise the key aspects of the model outputs from the base year model run. They can be split into three different types of outputs:

- Demand Outputs;
- Energy Consumption Outputs; and
- Emissions Outputs.

2.1.2 A more detailed analysis of these outputs is presented in the main outputs section.

2.2 Demand Outputs

2.2.1 The total person demand in Cesena is 312,500, which using average city-specific vehicle occupancies, equates to around 225,500 vehicles. This is on average 3.2 trips per person, with an average distance of around 5km. Figure 3 shows the number of vehicles broken down by type.

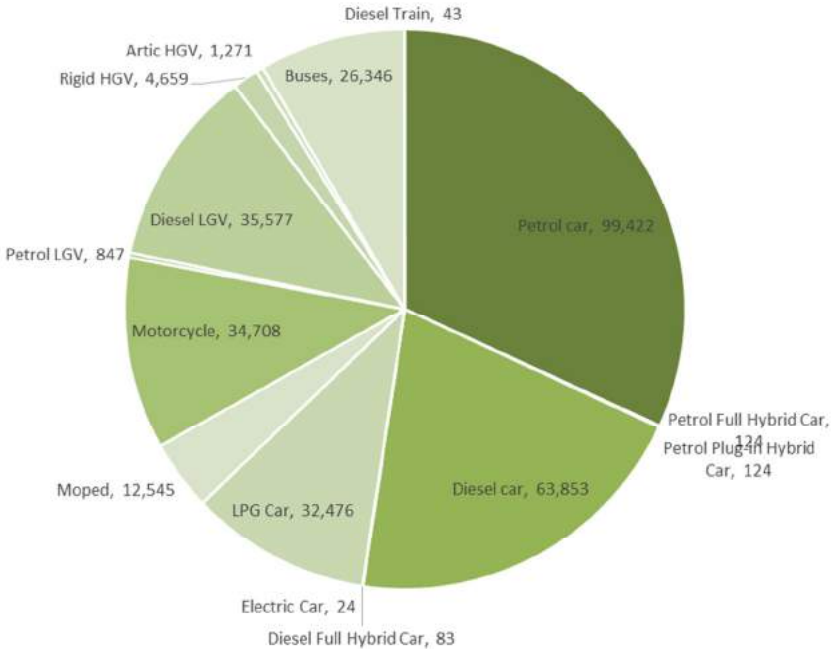

Figure 3. Demand By Vehicle Type

2.3 Energy Consumption Outputs

2.3.1 Table 1 presents a summary of the total energy used by transport within Cesena. The total daily value across all modes, vehicle types, purposes and zones is **7,076,076 MJ**, which is around 73MJ per person, per day.

2.3.2 It can be seen that more than half of the total energy used by transport in Cesena can be attributed to cars, which represent roughly two thirds of the total demand.

Table 1. Energy Usage Summary

NO	TOTAL	CARS	BIKES	GOODS	BUSES	TRAINS
Total Energy (MJ)	**7,076,076**	**4,064,280**	**836,511**	**1,884,301**	**174,528**	**116,457**
Population	96,875					
Energy Per Person (MJ)	73.0	42.0	8.6	19.5	1.8	1.2
Demand (Persons)	312,104	196,107	47,253	42,354	26,712	43
Energy Per Trip (MJ)	22.6	20.7	17.7	44.5	6.5	2,720.1
Trips Per Person	3.2	2.0	0.5	0.4	0.3	0.0
Actual Vehicles	84,139	56,493	18,810	7,853	916	68
Energy Per Vehicle (MJ)	84.1	71.9	44.5	240.0	190.5	1,712.6
Vehicles Per Person	0.87	0.58	0.19	0.08	0.01	0.001

2.3.3 Figure 4 shows the energy consumption aggregated to the zone the demand originates in. It can be seen that zones with high numbers of attractions, such as zone 1, often have a high energy usage, whereas zones with little population, such as zone 13, will often have a low energy usage. It can also be seen that the distance from key attractions affects the amount of energy consumed (i.e. from zone 10).

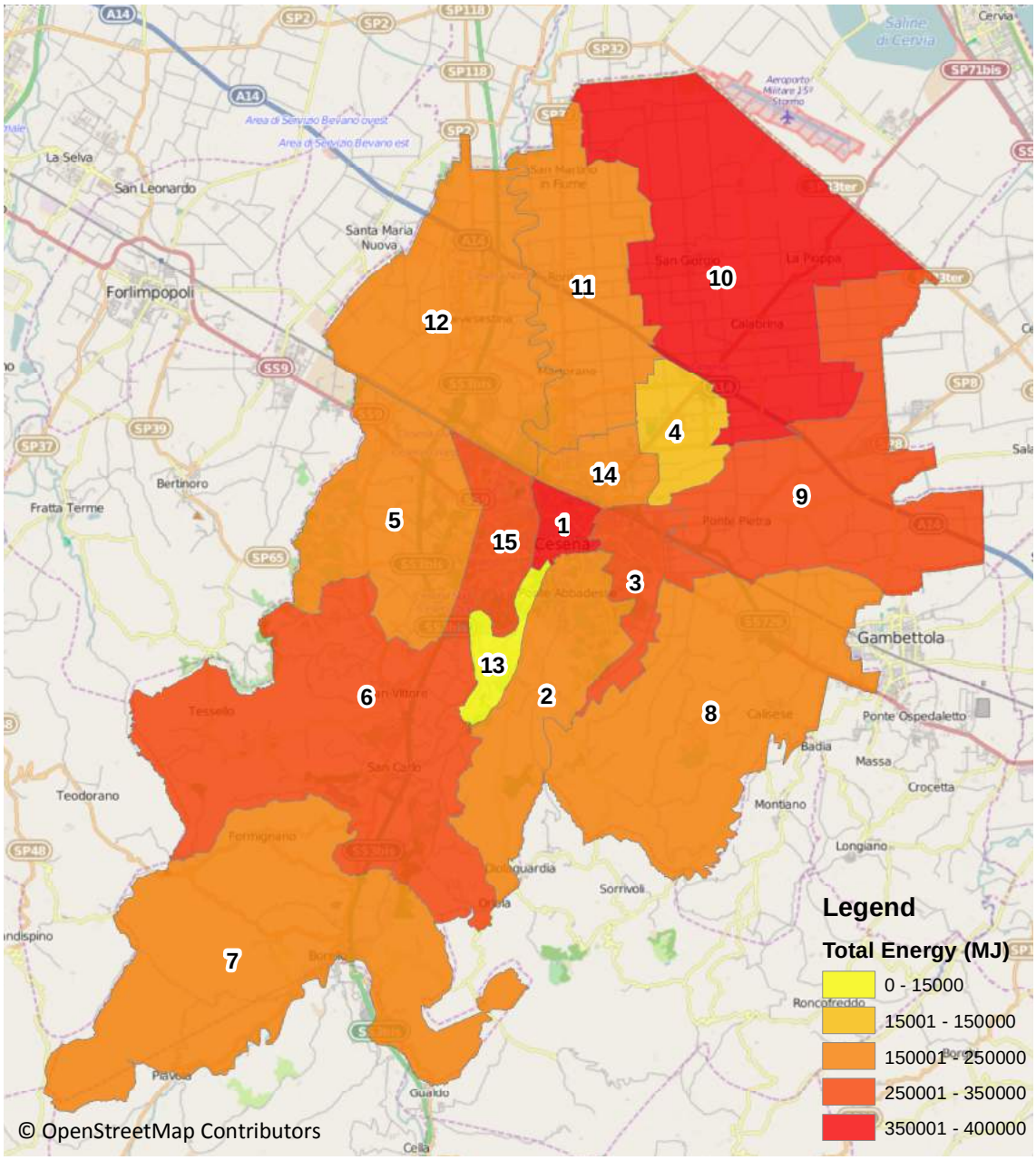

Figure 4. Total Energy (MJ) Per Origin Zone

2.4 Emissions Outputs

2.4.1 The model also reports the following emissions;

- Nitrous Oxides;
- Particulate Matter (PM10s);
- Hydro Carbons;
- Carbon Monoxide; and
- Carbon Dioxide.

2.4.2 Figure 5 demonstrates each of the emission types and the contribution each vehicle type has upon each emission. It can be seen that the splits here are very different depending on the emission type. Mopeds and Motorbikes are responsible for most of the Hydro-Carbons, PM10s and Carbon Monoxide emitted despite being only a small percentage of the total demand.

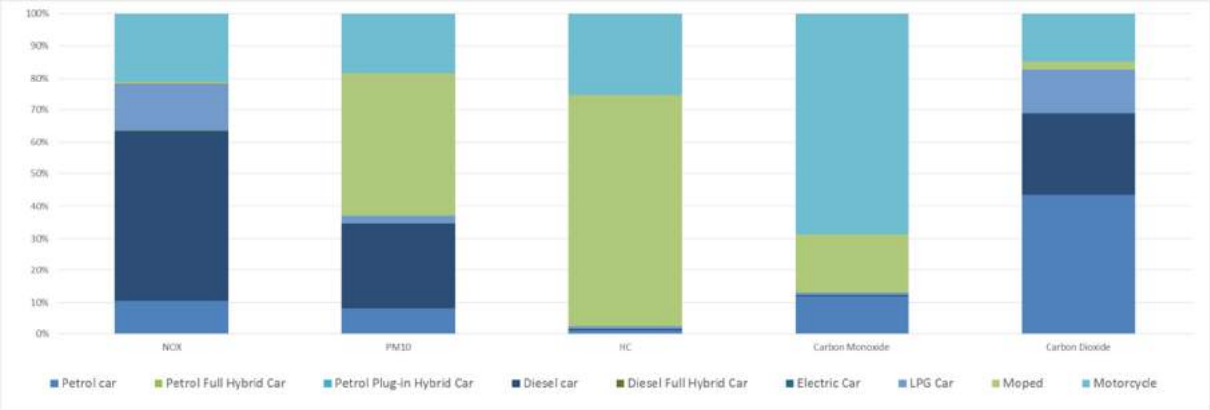

Figure 5. Emissions by Vehicle Type

3. INPUTS

3.1 Introduction

3.1.1 The inputs to the model can be broken down into three sets;

- Model specific inputs such as zoning, distances, public transport services, land use;
- Inputs common to all models such as trip purposes, vehicle types, modes etc;
- Parameters for the energy and emissions calculations and for the various transport choices (mode, destination, route).

3.1.2 This report covers only the first set – model specific inputs. In the following sections information is given on the main model-specific inputs and their sources. Inputs included are;

- Land Use – Residential and Non-Residential;
- Public Transport Routes;
- Distances;
- Speeds;
- Purpose Splits;
- Vehicle Type Splits;
- Public Transport Fares;
- Parking Charges; and
- Internal/External Demand splits.

3.2 Land Use

3.2.1 The land use is one of the most important inputs in the model. The number of dwellings, split into houses and flats, is multiplied by an average trip rate to give a total number of home-based trips per zone. These trips are then distributed amongst the non-residential land use locations based on journey time and the relative attractiveness and size of the non-residential attractors.

Residential

3.2.2 The number of houses and flats in each zone was calculated using the following process;

- Spread the total number of residential dwellings in Cesena (38,956) based on the number of families in each zone;
- Calculate the split between houses and flats by zone from the building survey information; and
- Apply the house/flat splits to the total number of dwellings in each zone.

3.2.3 The average occupancy per zone was checked and was found to be 2.49 persons per dwelling for the entire Cesena modelled area.

3.2.4 Table 2 shows the population and number of houses and flats by zone. Figure 6 shows the same information graphically.

Table 2. Population and Residential Land Use

NO	ZONE NAME	POP	FAMILIES	HOUSES	FLATS	TOTAL	AVE OCC
1	Centro Urban 2	11,421	5,738	1,484	3,906	5,390	2.12
2	Cesuola	5,089	2,231	1,796	299	2,095	2.43
3	Fiorenzuola	10,745	4,911	2,578	2,035	4,613	2.33
4	Cervese Sud 1	4,255	1,655	837	717	1,554	2.74
5	Oltre Savio1	4,650	1,860	1,247	499	1,747	2.66
6	Valle Savio	5,671	2,254	1,494	623	2,117	2.68
7	Borello	2,766	1166	912	183	1,095	2.53
8	Rubicone	5,082	1,992	1,650	220	1,871	2.72
9	Al Mare	6,825	2,675	2,170	343	2,512	2.72
10	Cervese Nord	6,501	2,505	2,265	87	2,352	2.76
11	Ravennate	5,347	2,111	1,854	128	1,982	2.70
12	Dismano	4,637	1,866	1,752	0	1,752	2.65
13	Centro Urban 1	310	135	119	7	126	2.44
14	Cervese Sud 2	9,170	4,072	1,391	2,434	3,825	2.40
15	Oltre Savio 2	14,406	6,302	2,089	3,830	5,920	2.43
	Total	**96,875**	**41,473**	**23,644**	**15,312**	**38,956**	**2.49**

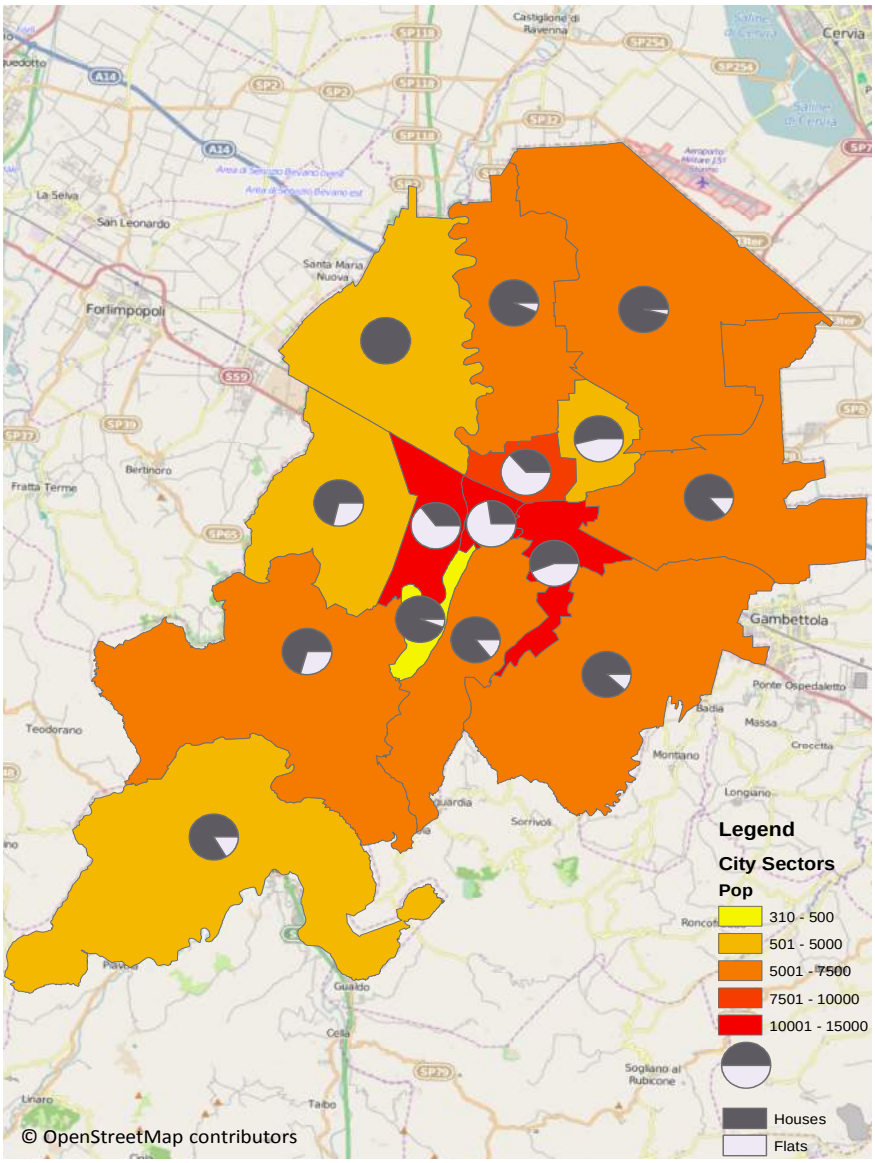

Figure 6. Population and Household Type Splits

Non-Residential:

3.2.5 Table 3 shows the non-residential land use. The data is input to the model at a more disaggregate level, but is summarised here for clarity. The groupings also reflect the data received – which was Employment, Retail and Education. Full details of the assumed land use splits can be found in Appendix A. The following text provides information on how the data was split.

3.2.6 **Employment**: The employment floorspace was split into Office and Other using the following factors;

- City Centre – 90% Office;
- Edge of City Centre – 70% Office;
- Suburban – 50% Office; and
- Rural & Outside City – 20% Office.

3.2.7 The "Other" employment was all allocated to the Industrial Unit land use type, with the exception of zone 12 which is assumed to be an Industrial Estate.

3.2.8 **Retail**: Splits between Food and Non-Food land use were provided for us. These were used to split the total Retail floorspace. Further splitting of the Food land use was undertaken using GIS.

3.2.9 **Education**: Education floorspace was split into Primary, Secondary and College/University using student numbers taken from an Education GIS layer which was provided for us.

3.2.10 **Other**: The Other land use is made up of sports facilities, stadia, hospitals, restaurants and cinemas identified through a GIS process.

Table 3. Non-Residential Land Use

NO	ZONE NAME	EMPLOYMENT	RETAIL	EDUCATION	OTHER
1	Centro Urban 2	134,387	98,103	134,955	20,907
2	Cesuola	-	878	19,197	34,238
3	Fiorenzuola	135,686	229,540	34,161	270,536
4	Cervese Sud 1	453,101	3,080	-	1,872
5	Oltre Savio1	366,086	15,078	-	38,647
6	Valle Savio	535,799	4,206	1,520	8,629
7	Borello	-	2,015	-	288
8	Rubicone	923,658	6,389	-	21,470
9	Al Mare	123,571	2,793	-	29,686
10	Cervese Nord	79,502	5,145	-	717
11	Ravennate	422,987	14,833	21,719	-
12	Dismano	2,317,975	1,946	-	8,190
13	Centro Urban 1	-	54,331	-	-
14	Cervese Sud 2	591,337	148,997	8,173	1,314
15	Oltre Savio 2	533,595	13,522	11,440	476,584
	Total	**6,617,684**	**600,856**	**231,165**	**913,078**

3.2.11 Figure 7 shows the land use figures as percentages of the total zonal land use.

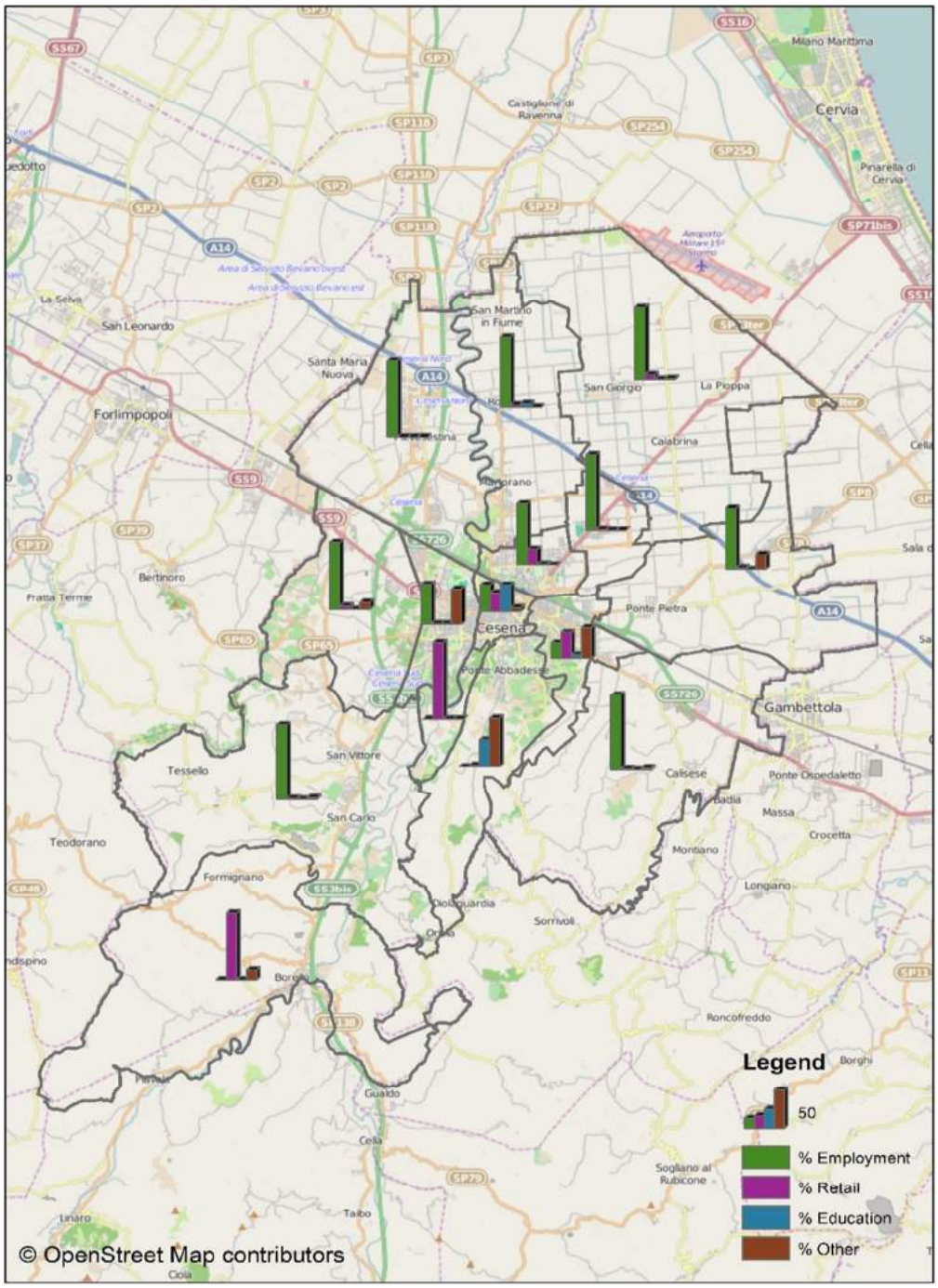

Figure 7. Percentage Land Use by Zone

3.3 Distances

3.3.1 The model calculates average travel times between zones using the average zone-zone distance and speeds. These distances have been obtained via an online routing service, choosing the most common route between the centre of each zone. The public transport distances follow the bus and rail service routes.

3.3.2 Figure 8 shows the Highway routes used, with the route between zones 1 and 9 highlighted as an example. For the highway (cars, motorbikes and mopeds) all movements are possible between all origin-destination combinations. As the Public transport distances have to follow Public Transport routes there are some movements where travel is not possible, and so no distance exists. This is particularly true for rail where the only movement is from zone 1 to the external zone 16.

3.3.3 Distances to the external zone are taken as the average distance from the Transport Survey to locations outside the study area.

3.3.4 Table 4 to Table 5 show the input distance matrices for highway, bus and rail respectively.

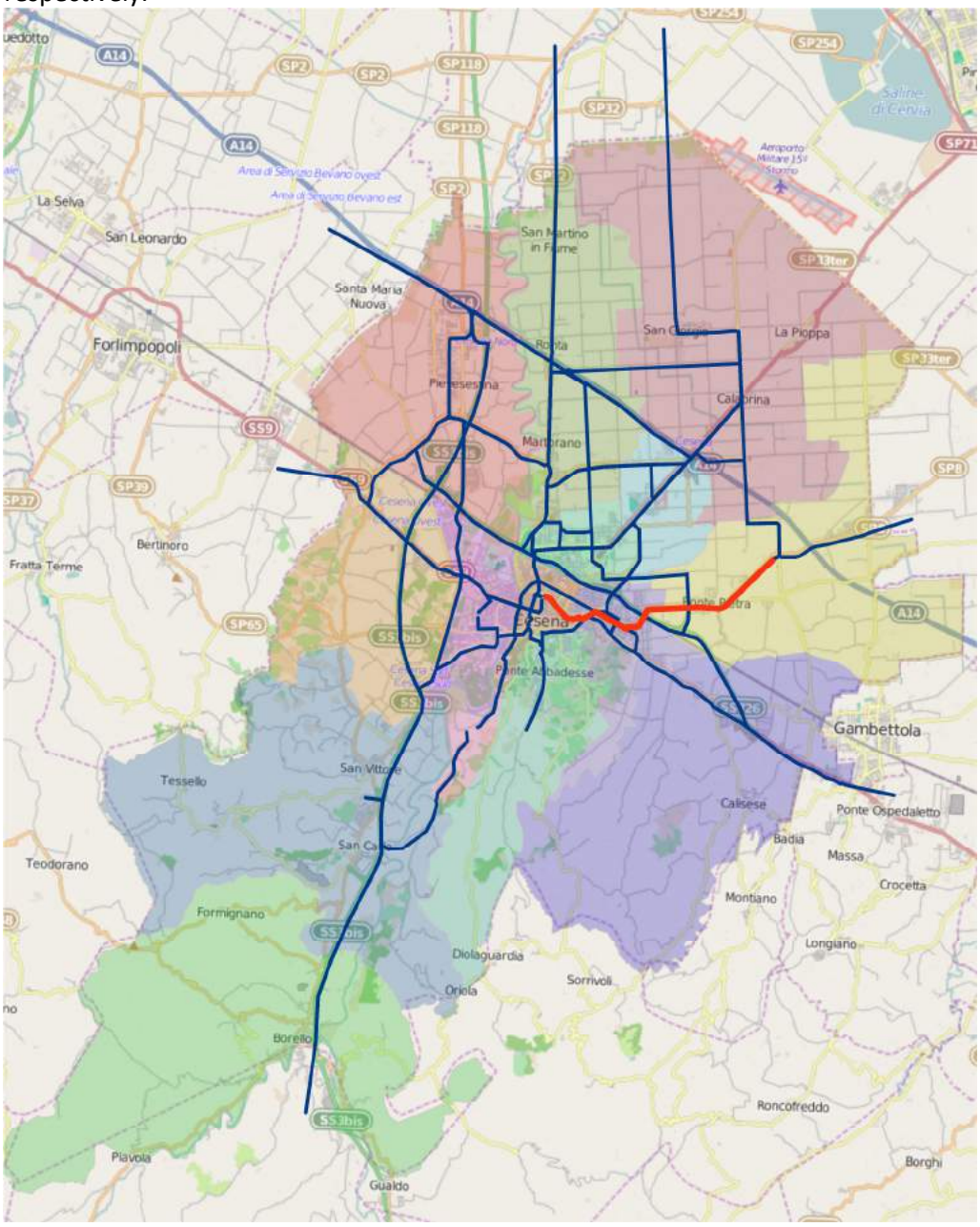

Figure 8. Highway Distances

Table 4. Highway Distances (Km)

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.0	2.9	1.9	3.7	3.5	7.0	12.0	5.9	6.1	10.4	8.4	7.2	3.3	2.2	2.0	93.8
2	2.9	1.4	4.9	7.0	7.3	10.4	15.7	9.3	9.1	13.6	10.7	10.9	7.4	5.5	5.8	0
3	1.9	4.9	1.0	5.3	5.7	8.9	14.2	4.7	4.4	11.7	10.2	9.5	5.9	3.5	4.3	93.8
4	3.7	7.0	5.3	0.7	7.8	11.0	16.2	9.1	9.3	6.6	7.6	11.5	8.0	1.4	6.4	0
5	3.5	7.3	5.7	7.8	1.0	9.4	14.6	10.6	10.1	14.5	12.2	6.6	5.8	6.3	2.0	93.8
6	7.0	10.4	8.9	11.0	9.4	2.6	5.2	13.6	13.2	17.7	14.8	13.8	7.9	9.6	7.9	93.8
7	12.0	15.7	14.2	16.2	14.6	5.2	2.6	18.6	18.4	22.9	20.0	19.1	13.1	14.8	13.2	93.8
8	5.9	9.3	4.7	9.1	10.6	13.6	18.6	2.3	9.1	15.7	12.8	14.5	10.6	7.6	9.1	93.8
9	6.1	9.1	4.4	9.3	10.1	13.2	18.4	9.1	2.2	15.9	14.6	13.7	10.2	7.8	8.6	93.8
10	10.4	13.6	11.7	6.6	14.5	17.7	22.9	15.7	15.9	3.3	14.2	18.2	15.1	8.1	13.0	0
11	8.4	10.7	10.2	7.6	12.2	14.8	20.0	12.8	14.6	14.2	2.2	15.7	12.2	4.3	10.7	0
12	7.2	10.9	9.5	11.5	6.6	13.8	19.1	14.5	13.7	18.2	15.7	3.3	10.2	10.1	9.1	0
13	3.3	7.4	5.9	8.0	5.8	7.9	13.1	10.6	10.2	15.1	12.2	10.2	1.7	6.5	4.4	0
14	2.2	5.5	3.5	1.4	6.3	9.6	14.8	7.6	7.8	8.1	4.3	10.1	6.5	0.7	4.9	0
15	2.0	5.8	4.3	6.4	2.0	7.9	13.2	9.1	8.6	13.0	10.7	9.1	4.4	4.9	1.0	93.8
16	93.8	0	93.8	0	93.8	93.8	93.8	93.8	93.8	0	0	0	0	0	93.8	0
Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.0	3.5	2.0	4.3	3.6	8.1	12.8	8.2	6.3	9.3	5.2	6.7	3.6	2.3	2.1	40.84
2	3.5	1.7	4.2	7.8	6.4	8.7	13.5	8.6	8.5	11.4	8.4	9.9	5.3	5.5	4.2	40.84
3	2.0	4.2	1.0	3.5	7.2	13.4	18.2	4.9	4.4	8.0	7.4	8.7	5.6	2.9	4.2	40.84
4	4.3	7.8	3.5	1.0	13.0	19.2	23.9	8.1	5.3	4.4	5.7	7.2	7.6	2.0	6.0	40.84
5	3.6	6.4	7.2	13.0	1.2	6.6	11.4	11.5	11.0	15.0	8.7	5.1	5.8	6.2	2.5	40.84
6	8.1	8.7	13.4	19.2	6.6	2.5	5.5	17.7	17.3	21.2	14.4	10.8	5.0	12.5	7.0	40.84
7	12.8	13.5	18.2	23.9	11.4	5.5	0.3	22.4	22.0	26.0	19.1	15.6	7.8	17.2	11.8	40.84
8	8.2	8.6	4.9	8.1	11.5	17.7	22.4	0.7	6.3	12.1	11.4	13.0	11.5	7.5	9.9	40.84
9	6.3	8.5	4.4	5.3	11.0	17.3	22.0	6.3	1.1	5.8	11.0	12.5	11.1	6.0	11.6	40.84
10	9.3	11.4	8.0	4.4	15.0	21.2	26.0	12.1	5.8	2.2	5.0	10.7	12.6	6.5	11.0	40.84
11	5.2	8.4	7.4	5.7	8.7	14.4	19.1	11.4	11.0	5.0	2.1	5.5	8.5	4.6	6.9	40.84
12	6.7	9.9	8.7	7.2	5.1	10.8	15.6	13.0	12.5	10.7	5.5	1.6	9.3	6.3	6.0	40.84
13	3.6	5.3	5.6	7.6	5.8	5.0	7.8	11.5	11.1	12.6	8.5	9.3	1.8	5.6	3.6	40.84
14	2.3	5.5	2.9	2.0	6.2	12.5	17.2	7.5	6.0	6.5	4.6	6.3	5.6	1.0	3.9	40.84
15	2.1	4.2	4.2	6.0	2.5	7.0	11.8	9.9	11.6	11.0	6.9	6.0	3.6	3.9	1.0	40.84
16	40.84	40.84	40.84	40.84	40.84	40.84	40.84	40.84	40.84	40.84	40.84	40.84	40.84	40.84	40.84	0

Table 5. Bus Distances (Km)

Table 6. Rail Distances (Km)

Final Dist	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	93.8
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
16	93.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.4 Public Transport Routes

3.4.1 The main 15 bus routes in Cesena are included in the model. Figure 9 shows the routes that the services follow. The routes shown extending outside of the modelled area provide routes to the external zone. Table 7 gives details of the routes included and the number of buses per day.

3.4.2 In addition to the bus services there is a train service from zone 1 to the external zone 16.

3.4.3 Public Transport demand is allowed to take any route that is either direct, or involves one transfer. The route choice model then distributes the demand amongst all the possible routes for a given movement based on the generalised cost of the journey (made up of travel time, wait time, walking time, fare etc).

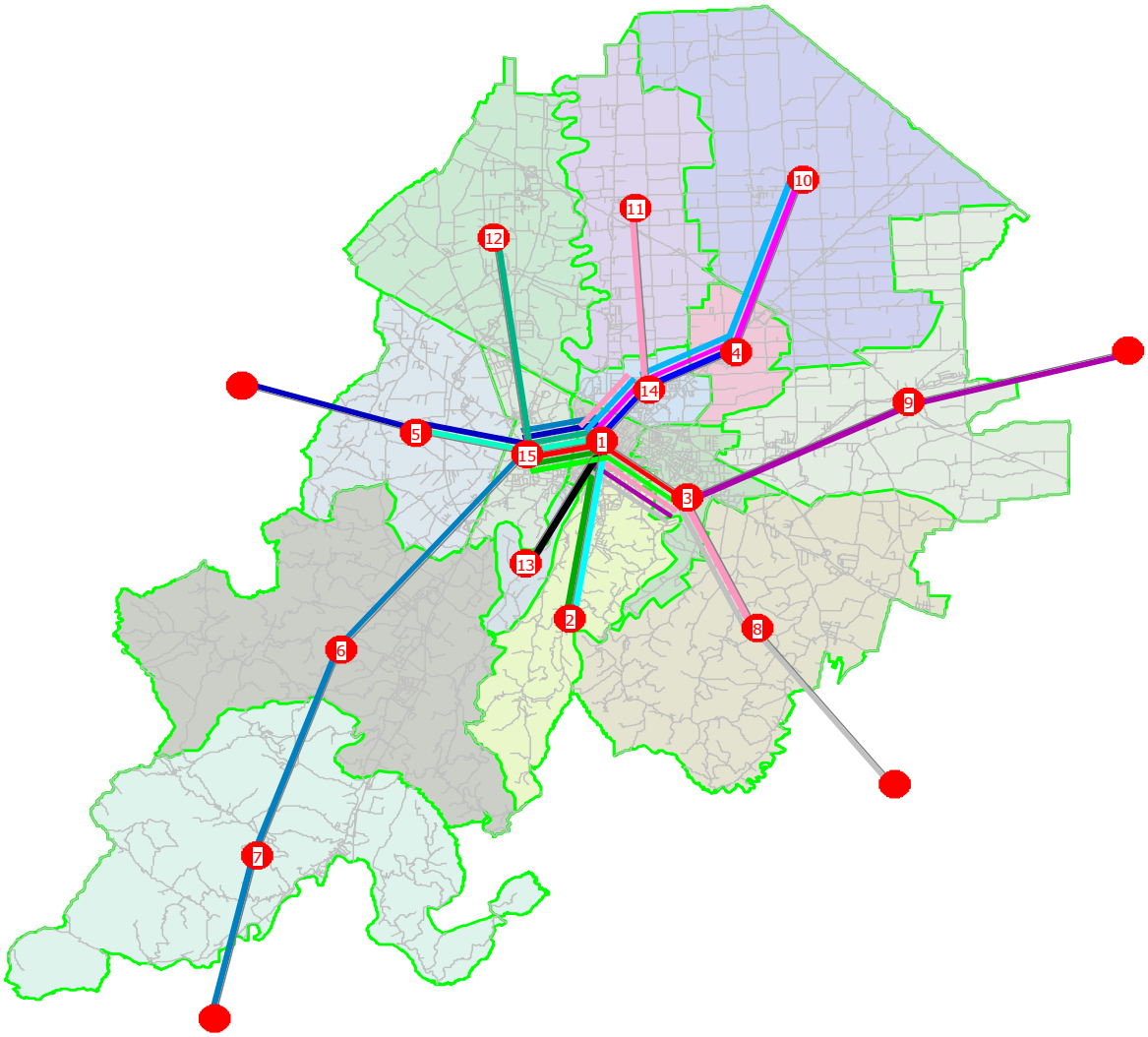

Figure 9. Public Transport Routes

Table 7. Public Transport Routes

ROUTE NO		FROM	TO	ZONE FROM	ZONE TO	BUSES PER DAY
	1	Barriera Terminal	Park Autostrada	1	4	35
	3	Arcangeli	Cimitero Nuovo	15	3	50
	4	Ippodromo	Ospedale	2	15	75
	5	Rio Eremo	Stazione FS	2	1	60
	6	Rio Maggiore	Montefiore	15	3	60
	11	Bagnile	Barriera Terminal	10	1	20
	12	Capannaguzzo	Barriera Terminal	10	1	5
	13	Stazione FS	Tipano	1	5	6
	21	S. Martino in Fiume	Gambettola	11	8	24
	31	Roversano Castello	Punto Bus	13	1	1
	41	S. Andrea in Bagnolo	Stazione FS	1	12	16
	92	Punto Bus	Forli FS	1	16	49
	93	Punto Bus	Borello Peep	1	7	21
	94	Punto Bus	Cesenatico Porto Canale	1	16	21
	95	Punto Bus	Savignano	1	16	34

3.5 Speeds

3.5.1 The speeds in the model are specified by Vehicle Type and Area Type. Table 8 shows the speeds used in the model, aggregated to groups of vehicle types with the same sets of speed. The groupings are;

- Cars: Petrol, Diesel, Petrol Full Hybrid, Diesel Full-Hybrid, Electric, LPG cars and Taxis;
- Goods Vehicles: Petrol and Diesel LGVs, Rigid and Artic HGVs;
- Buses: Diesel, Hybrid, Electric and Gas-powered buses; and
- Trains: Diesel and Electric trains.

Table 8. Speeds by Vehicle and Area Type (Km/h)

VEHICLE TYPE	CITY CENTRE	EDGE OF CITY CENTRE	SUBURBAN	RURAL/ OUTSIDE CITY	EXTERNAL
Cars	40	50	50	50	90
Goods Vehicles	30	40	40	40	50
Buses	40	50	50	50	90
Mopeds/Motorbikes	40	50	50	50	90
Trains	90	90	90	90	90

3.6 Purpose Splits

3.6.1 The home-based trips are split into purposes using zonal purpose splitting factors. These have been calculated from the Transport Survey data. For the Retail and Education purposes where the percentage split was less than the average for the whole city the average split was used. The Work and Other purposes were then factored down to retain 100% across all purposes.

3.6.2 Table 9 shows the zonal purpose splits used, with Figure 10 showing the variation graphically. Figure 11 shows the average purpose splits across the whole city.

Table 9. Residential Purpose Splits

	Zone	Office	Industry / Warehousing	Retail Food	Retail Non-Food	Primary School	Secondary School	College	Other	All Purposes
1	Centro Urban 2	13%	7%	1%	6%	9%	3%	5%	55%	100%
2	Cesuola	37%	20%	2%	10%	2%	1%	1%	27%	100%
3	Fiorenzuola	27%	15%	1%	6%	2%	1%	1%	46%	100%
4	Cervese Sud 1	28%	16%	1%	6%	2%	1%	1%	44%	100%
5	Oltre Savio1	20%	11%	1%	7%	2%	1%	1%	56%	100%
6	Valle Savio	21%	12%	1%	6%	2%	1%	1%	55%	100%
7	Borello	23%	13%	1%	6%	2%	1%	1%	53%	100%
8	Rubicone	20%	11%	1%	6%	6%	2%	3%	51%	100%
9	Al Mare	21%	12%	1%	6%	2%	1%	1%	55%	100%
10	Cervese Nord	30%	17%	1%	6%	2%	1%	1%	41%	100%
11	Ravennate	17%	9%	1%	6%	2%	1%	1%	62%	100%
12	Dismano	30%	17%	1%	6%	3%	1%	1%	41%	100%
13	Centro Urban 1	38%	22%	3%	17%	5%	2%	3%	10%	100%
14	Cervese Sud 2	29%	16%	1%	8%	2%	1%	1%	41%	100%
15	Oltre Savio 2	18%	10%	1%	6%	4%	2%	2%	56%	100%
	Average	25%	14%	1%	6%	2%	1%	1%	48%	100%

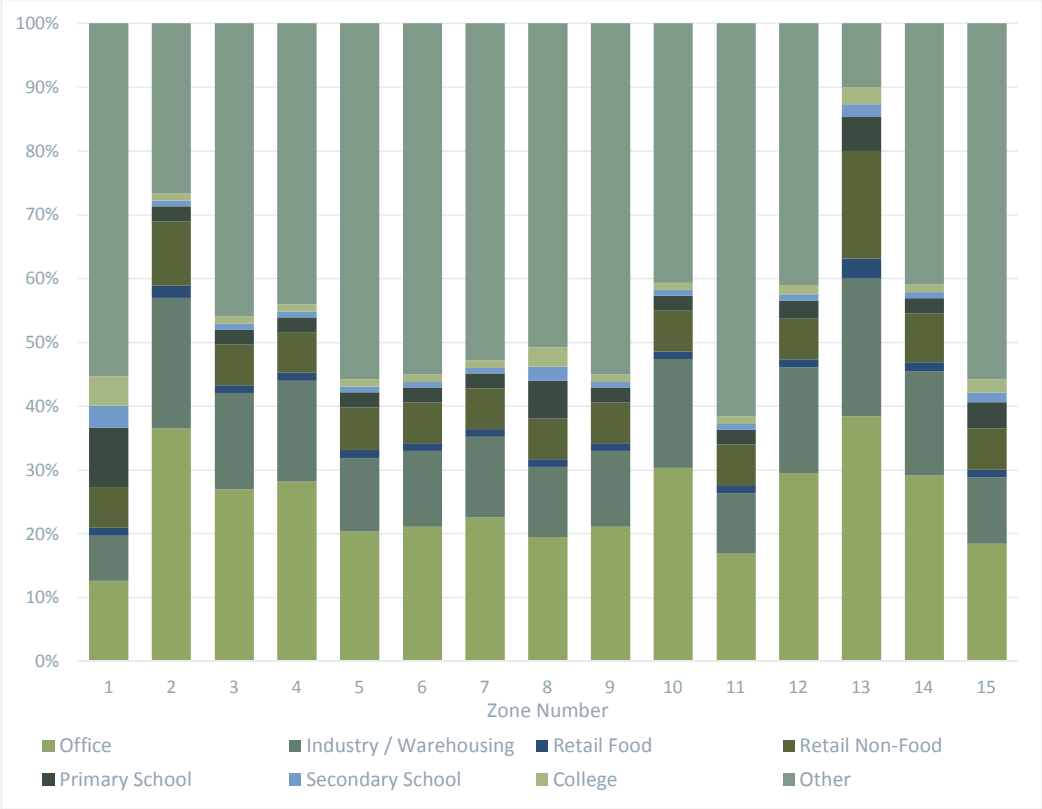

Figure 10. Residential Purpose Splits By Zone

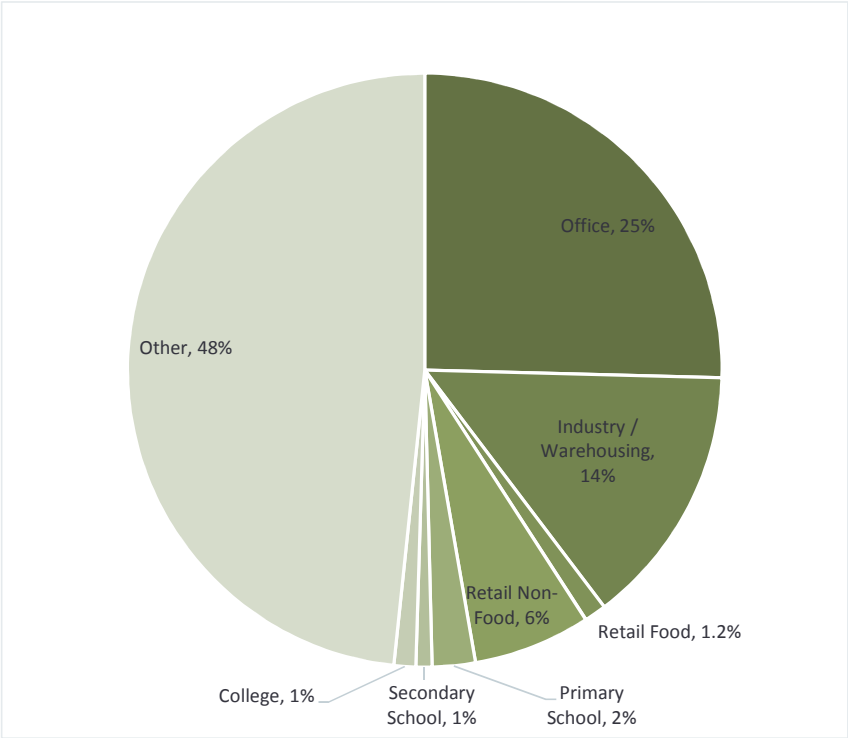

Figure 11. Average Residential Purpose Splits

3.7 Vehicle Splits

3.7.1 The vehicle type splits were calculated using the following process;

- The split between Petrol, Diesel and LPG cars was taken from 2009-2011 vehicle fleet information provided by Cesena. This gave the following splits;
  - Petrol: 50.9%
  - Diesel: 32.6%
  - LPG: 16.6%
- Figures for Hybrid and Electric cars were calculated from Italian sales data from 2001 to 2013. These were taken from the International Council on Clean Transportation website[1]. This gives a share of 0.17% for Hybrids, which is then broken down to the different Hybrid types using UK fleet data. The electric share is 0.01%.
- The split between cars, mopeds and motorbikes were taken from the European Commission Statistical Pocketbook 2012[2]. For Italy this gave the following;
  - 19% of vehicles are motorbikes or mopeds; and
  - 73% of these two-wheelers are motorbikes.

3.7.2 Combining these statistics gives the vehicle splits shown in Table 10 and Figure 12.

Table 10. Vehicle Splits – Highway

ID	VEHICLE TYPE	PERCENTAGE SPLIT
1	Petrol car (inc Taxis)	40.85%
2	Diesel car (inc Taxis)	26.24%
3	Petrol Full Hybrid Car	0.05%
4	Diesel Full Hybrid Car	0.03%
5	Petrol Plug-in Hybrid Car	0.05%
6	Electric Car	0.01%
15	Moped	5.16%
16	Motorcycle	14.26%
17	LPG Car	13.35%

[1] http://www.theicct.org/sites/default/files/publications/EU_pocketbook_2014.pdf
[2] http://ec.europa.eu/transport/facts-fundings/statistics/doc/2012/pocketbook2012.pdf

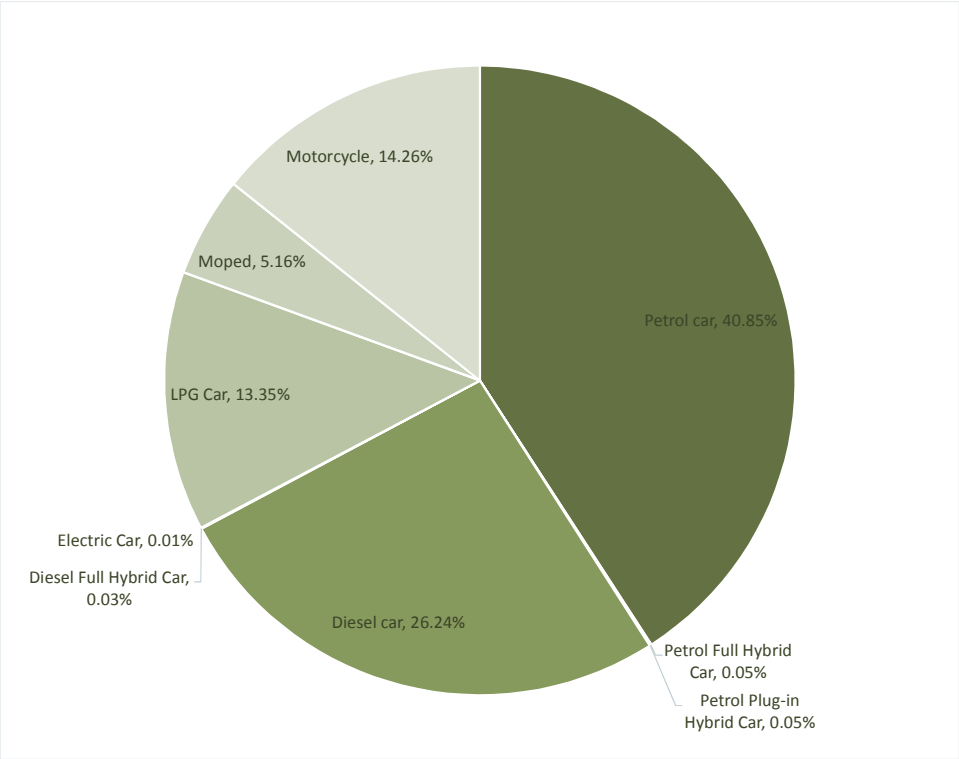

Figure 12. Highway Vehicle Splits

3.7.3 The split between different goods vehicles was taken from 2013 UK fleet split data as no Italian data could be sourced. The values used are shown in Table 11 and Figure 13.

Table 11. Goods Vehicle Splits

ID	VEHICLE TYPE	PERCENTAGE SPLIT
7	Petrol LGV	2.00%
8	Diesel LGV	84.00%
9	Rigid HGV	11.00%
10	Artic HGV	3.00%

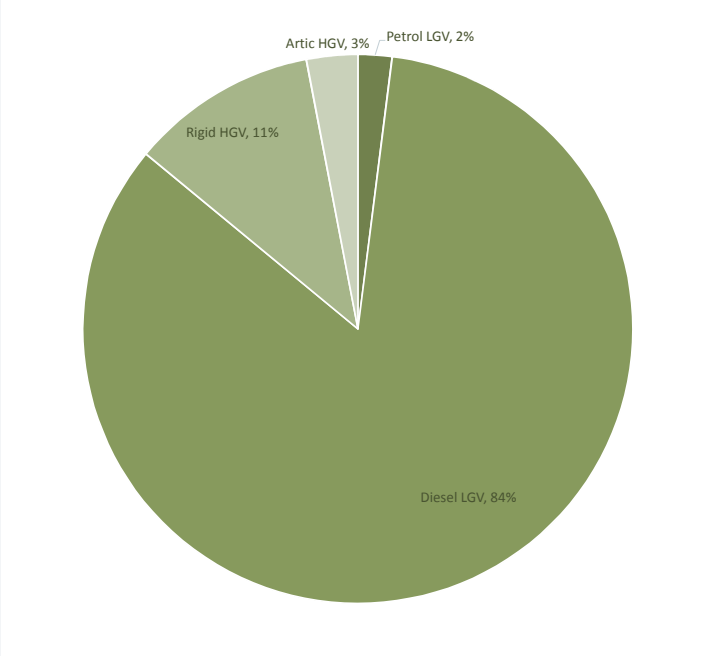

Figure 13. Goods Vehicle Splits

3.8 Parking

3.8.1 Cesena has 10 car parks around the city centre, all situated within zone 1. The parking charge is €0.60 an hour. Details of the car parks are shown in Table 12.

3.8.2 **Note**: There is no modelling of parking capacity within the model. The cost of parking is an additional cost included when travelling to a zone with car parking.

3.8.3 Parking charges represent an average charge incurred by all trips terminating in the zone containing the car park.

3.8.4 To calculate the total cost of parking for each purpose it has been assumed that work-based purposes (Office & Industry/Warehousing) park for an eight hour working day. All other purposes (Retail, Education and Other types) are assumed to park for two hours.

3.8.5 In addition, the charges have been reduced by one third to reflect the availability of work-place parking and free on-street parking. The resulting fares are shown in Table 13.

Table 12. Car Parks In Cesena

CAR PARK NAME	CAPACITY	PRICE (€/HR)	ZONE
Piazza Sanguinetti	78	€0.60	1
Machiavelli	188	€0.60	1
Giacomoni	23	€0.60	1
IV novembre	260	€0.60	1
Osservanza	155	€0.60	1
Barriera	168	€0.60	1
Martini	230	€0.60	1
Gasometro	64	€0.60	1
Mattarella	268	€0.60	1
Machiavelli	188	€0.60	1

Table 13. Parking Charges by Zone

ZONE		WORK	OTHER
1	Centro Urban 2	€3.20	€0.80

3.9 Internal & External Demand Splits

3.9.1 The external demand to and from the city is created by factoring the internal demand. This factor is taken from the Transport surveys. For Cesena the internal percentage is 81% of the total demand. This percentage is applied to highway (cars, mopeds and motorbikes), PT and goods demand as there is not sufficient information to get individual splits.

3.10 Public Transport Fares

3.10.1 The public transport fares are different for buses and trains. Buses use a fare matrix, giving zone-zone fares. The zonal structure is based on the Area Types, with trips between Area Types 1, 2 & 3 paying €1.00, and trips further out to Area Types 4 paying €2.00. Trips to the external zone pay €6.00. The full fare matrix is shown in Table 14.

3.10.2 The rail fares are distance based and use a price per km, which is multiplied by the distance travelled to get the fare. The cost per km was calculated using the fare from Cesena to Forli, which is €2.15 (taken from http://www.trenitalia.com) and covers approximately 26km. This gives a cost per km of €0.08 per km.

3.10.3 A validation check on the 90km journey from Cesena to Bologna, which costs around €8 (depending on the type of ticket), gives a similar figure of €0.09 per km.

Table 14. Bus Fares By Area Type

AREA TYPE	CITY CENTRE	EDGE OF CITY CENTRE	SUBURBAN	RURAL/OUT SITE CITY	EXTERNAL
CITY CENTRE	€1.00	€1.00	€1.00	€2.00	€6.00
EDGE OF CITY CENTRE	€1.00	€1.00	€1.00	€2.00	€6.00
SUBURBAN	€1.00	€1.00	€1.00	€2.00	€6.00
RURAL/OUTSIDE CITY	€2.00	€2.00	€2.00	€1.00	€6.00
EXTERNAL	€6.00	€6.00	€6.00	€6.00	N/A

4. CALIBRATION

4.1 Introduction

4.1.1 The model has been calibrated based on the Transport Survey data by looking at mode shares and average trip lengths. The quality of the public transport calibration is limited by the lack of data for this mode in the survey, which is felt to be under-represented. Only 17 trips were recorded as using public transport. This compares to 395 records for highway trips.

4.2 Mode Share

4.2.1 The Transport Survey has a car mode share of 96% across all zones and purposes. The model has a mode share of 91% - slightly less than observed, but acceptable. This is particularly true given the lack of public transport journeys in the survey information.

4.2.2 Figure 14 shows the global modelled mode share. Figure 15 shows the mode share by purpose, with the work-based purposes having the highest car share. The model is calibrated to mode share values by zone and purpose, where this data is available from the Transport Surveys. Where no data was available for a given zone the average across all zones was used.

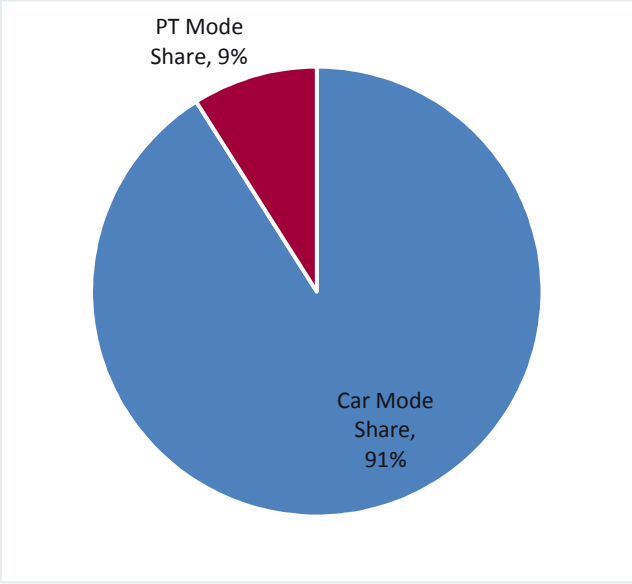

Figure 14. Global Mode Share

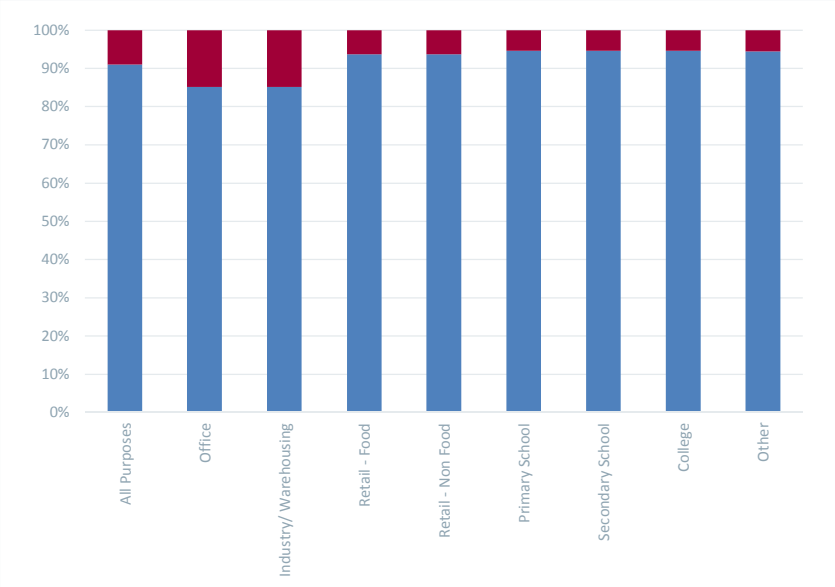

Figure 15. Mode Share by Purpose

4.3 Trip Length Distributions

4.3.1 The Transport Survey has average trip lengths for private vehicles (cars and motorbikes/mopeds) and public transport of 4.8km and 3.5km respectively. The modelled values are 4.7km and 4.2km.

4.3.2 The match of the highway to both average trip lengths and the overall trip length distribution is very good. Figure 16 shows the relative and cumulative frequencies of the observed and model distributions. Figure 17 shows the average trip lengths by purpose, which also shows a good match.

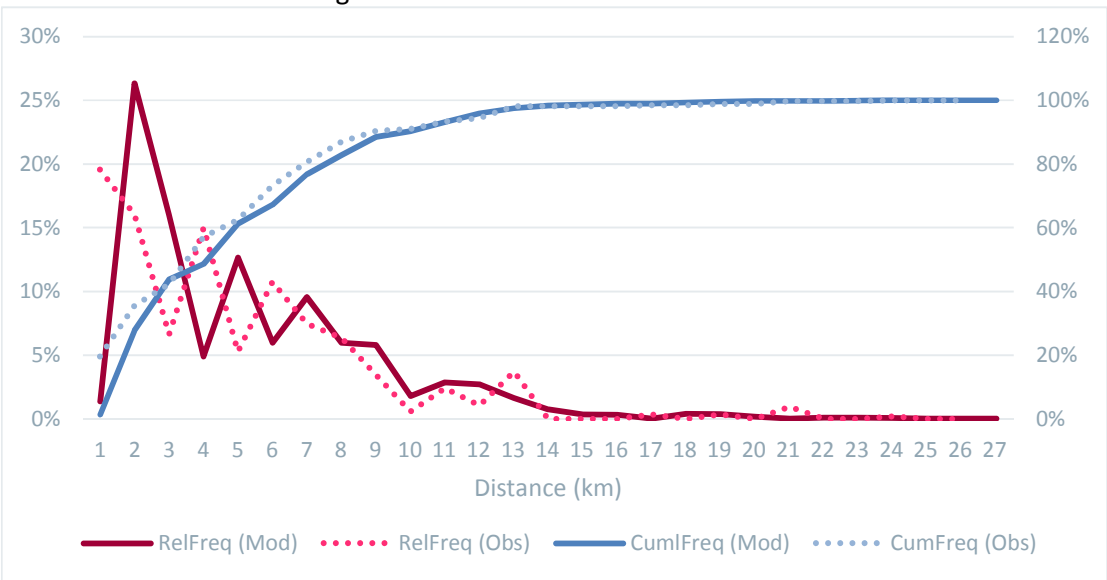

Figure 16. Highway Trip Length Distributions

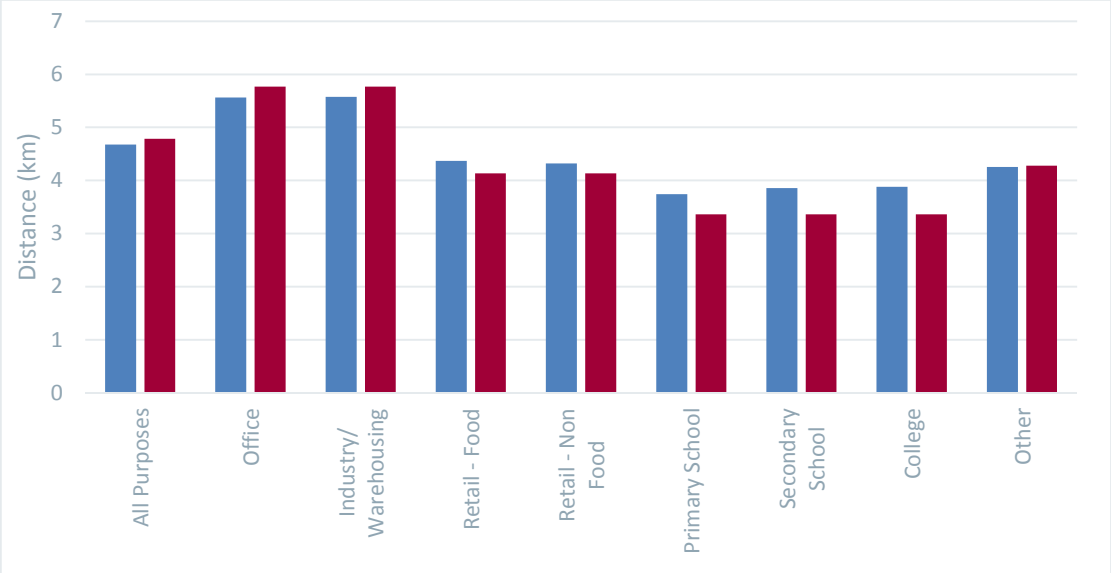

Figure 17. Highway Average Trip Lengths

4.3.3 The public transport distributions show a less good match, under-estimating the number of short distance trips, particularly for "Other" trips. Figure 18 showing the distribution and Figure 19 showing the average trip lengths by purpose both illustrate this.

4.3.4 Furthermore, Figure 16 also highlights the lack of public transport observed data as there are no trips at all for retail or education purposes and only two trips for "Other".

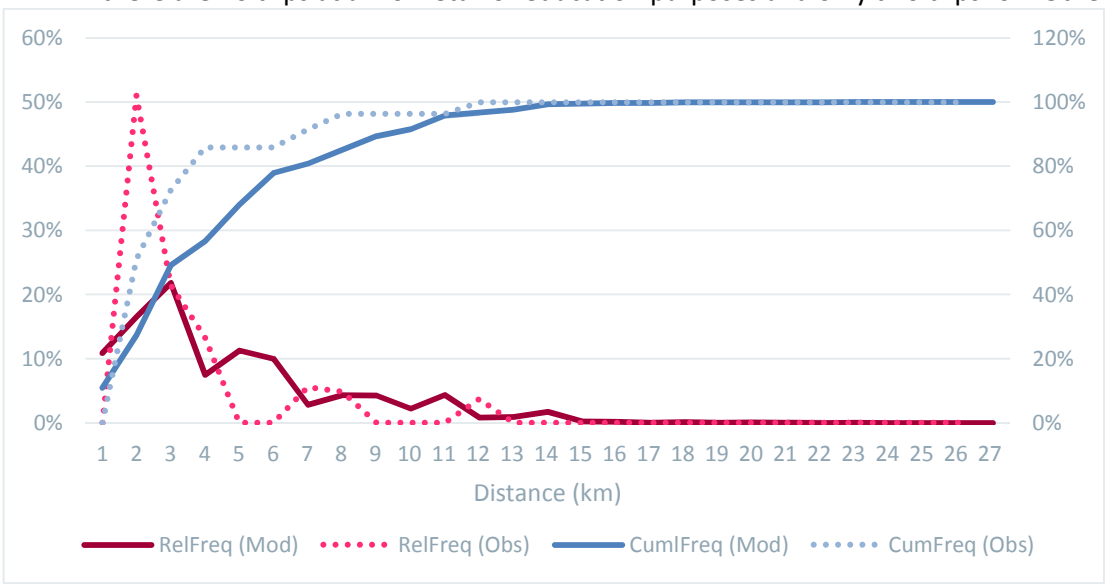

Figure 18. Public Transport Trip Length Distributions

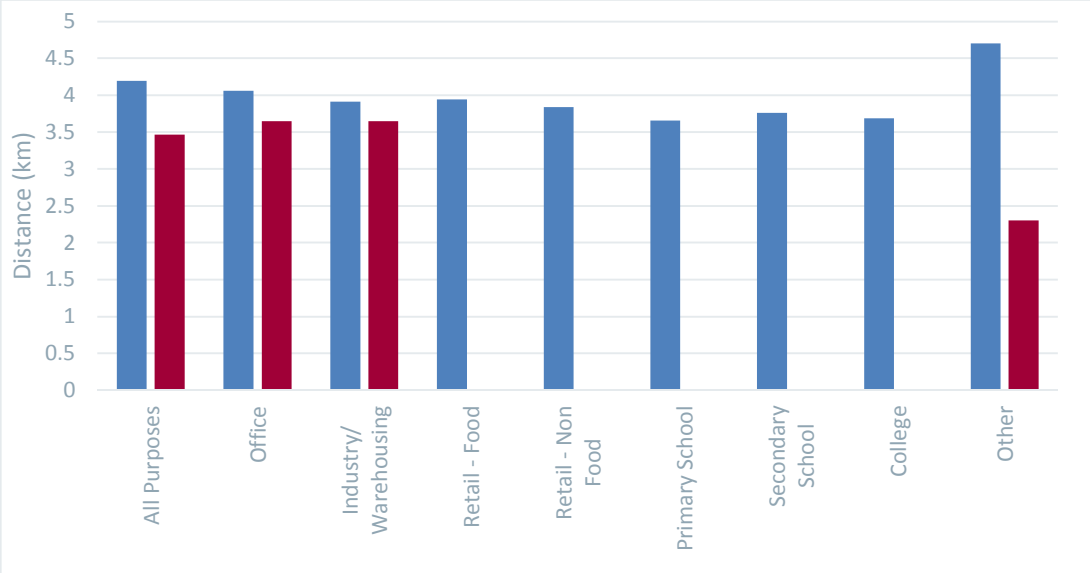

Figure 19. Public Transport Average Trip Lengths

5. OUTPUTS

5.1 Introduction

5.1.1 This section looks at the outputs from the base year model run. It is split into three sections;

- **Demand Outputs** – by Origin, Destination, Vehicle Type and a comparison to actual vehicle numbers;
- **Energy Consumption Outputs** – Total energy, per person, per trip and split by vehicle type; and
- **Other Emissions Outputs** – Carbon Dioxide, Hydro Carbons, PM10s and Nitrous Oxide emissions.

5.2 Demand Outputs

5.2.1 This section looks at the various demand outputs, checking they reflect the observed characteristics of the city. These include;

- Origin & Destination Plots;
- Demand by Purpose and Vehicle Type;
- Trip Rate checks;
- Comparison to actual vehicle figures; and
- Zone-Zone demand matrices.

5.2.2 Figure 20 shows the Origins and Destinations of the demand by zone. The origins match the distribution of houses and flats, which is to be expected as all the trips are home-based.

5.2.3 Zones 3 and 15 have the most demand going to them, with 24% and 27% of the total destinations respectively. Zone 3 has a large amount of retail and other floorspace (38% and 30% of the totals respectively). Zone 15 has over half of the Other floorspace – mostly in the form of a large leisure centre/park.

5.2.4 In addition zone 12 attracts a large amount of demand, mainly due to it containing a large out-of-town industrial area, representing 38% of the total Work floorspace in the city.

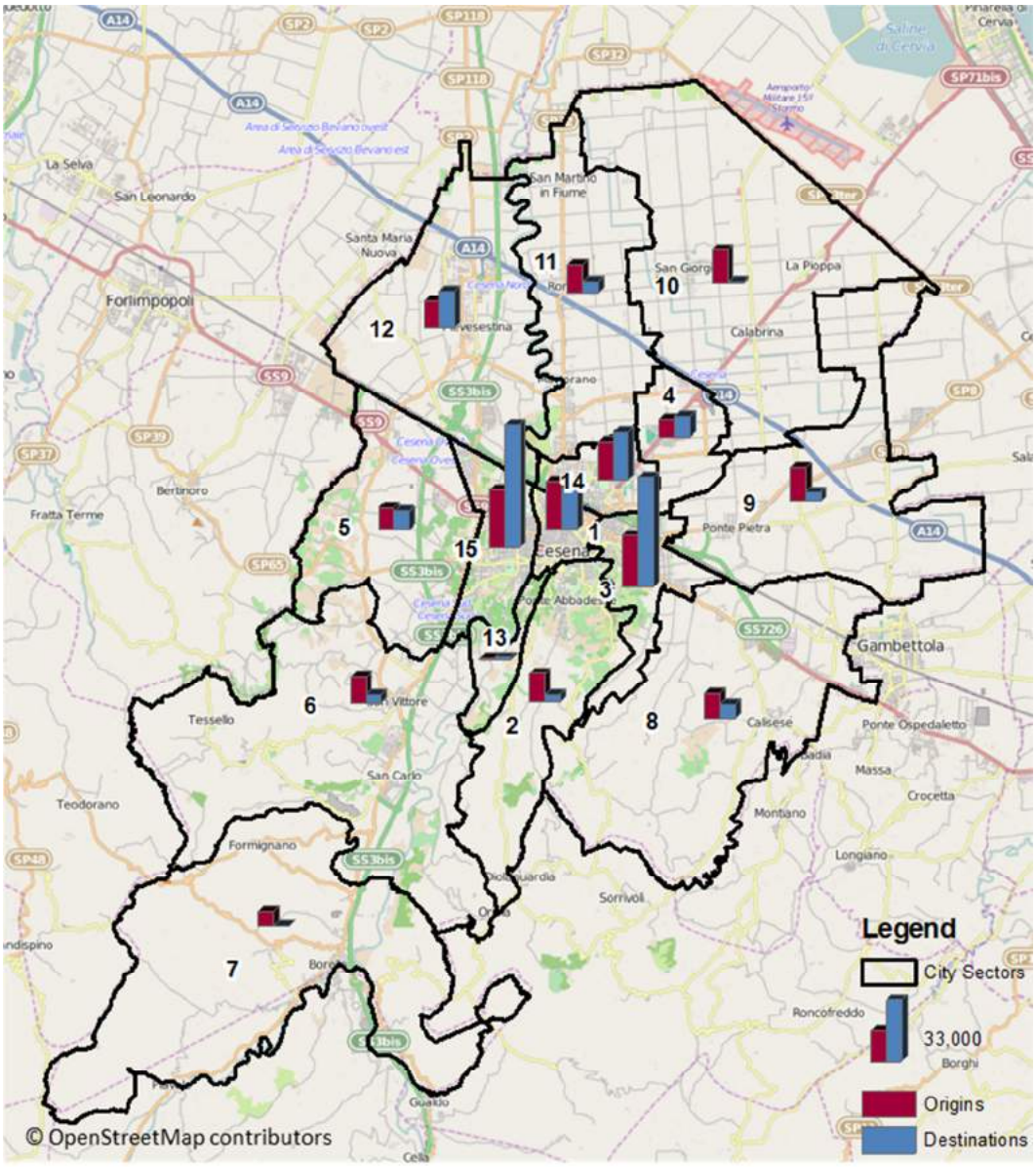

Figure 20. Origin & Destination Demand

5.2.5 Table 15 shows the demand split by purpose and mode (highway and PT). Highway based modes (including cars and motorbikes) make up most of the demand, particularly for work based purposes. The public transport mode share is highest for Employment and Other trips.

5.2.6 Table 15 also shows the average implied trip rate, per household, for each mode and purpose. Overall there are 2.76 two-way trips made each day per person. This is slightly higher than the 1.5 trips per person from the Transport Survey, though that doesn't include retail or education trips. Comparing just Employment and Other trip rates gives 2.35 trips per person; again higher than the transport survey and potentially suggesting a lower rate of trip making in Italy than in the UK.

5.2.7 Figure 21 shows the purpose splits of the implied trip rates for each mode, highlighting the large number of "Other" trips on PT. Demand and Trip Rates By Purpose.

Table 15. Demand and Trip Rates By Purpose

PURPOSE	HIGHWAY DEMAND	PT DEMAND	HY TRIP RATE	PT TRIP RATE	TOTAL TRIP RATE
Commute - Office	53,153	9,237	0.55	0.095	0.64
Commute - Industrial/Warehousing	29,839	5,186	0.31	0.054	0.36
Retail - Food	3,203	215	0.03	0.002	0.04
Retail - Non Food	17,004	1,140	0.18	0.012	0.19
Education - Primary	9,024	512	0.09	0.005	0.10
Education - Secondary	3,378	192	0.03	0.002	0.04
Education - College	4,504	256	0.05	0.003	0.05
Other	123,256	7,278	1.27	0.075	1.35
Total	243,360	24,016	2.51	0.248	2.76
Mode Share	91%	9%			

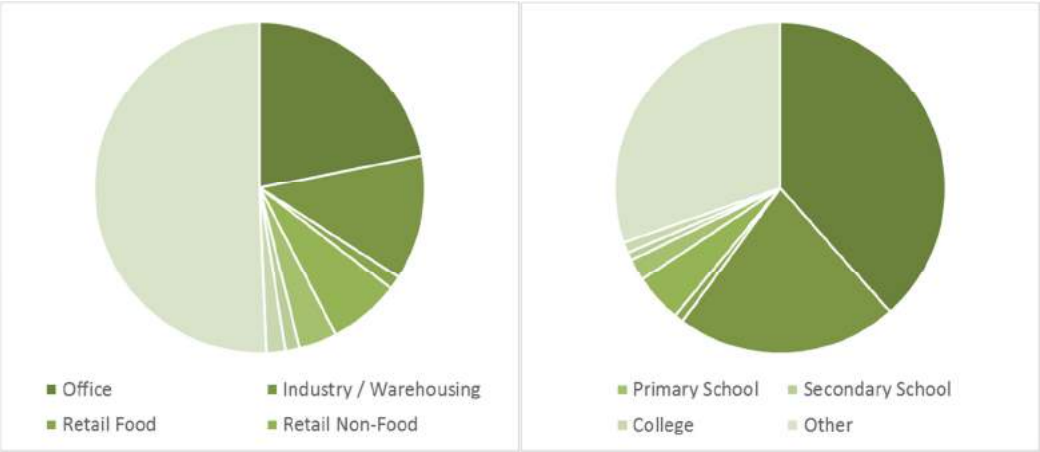

Figure 21. Highway & PT Trip Rates By Purpose

5.2.8 Table 16 shows the demand split into Vehicle Types and total vehicle kilometres. For the Private vehicles and Goods vehicles this reflects the Vehicle Splits input to the model. Public transport demand makes up 9% of the total demand, but less than 1% of vehicles.

5.2.9 Figure 22 shows the vehicle type splits graphically.

Table 16. Demand By Vehicle Type

VEHICLE TYPE	PERSON DEMAND	VEHICLE DEMAND	% PERSON	% VEHICLES	VEHICLE KMS
Petrol car	99,422	71,947	32%	32%	836,421
Petrol Full Hybrid Car	124	90	0%	0%	1,044
Petrol Plug-in Hybrid Car	124	90	0%	0%	1,044
Diesel car	63,853	46,207	20%	20%	537,182
Diesel Full Hybrid Car	83	60	0%	0%	696
Electric Car	24	18	0%	0%	205
LPG Car	32,476	23,502	10%	10%	273,218
Moped	12,545	12,545	4%	6%	144,890
Motorcycle	34,708	34,708	11%	15%	400,857
Petrol LGV	847	684	0%	0%	7,573
Diesel LGV	35,577	28,724	11%	13%	318,078
Rigid HGV	4,659	4,659	1%	2%	51,317
Artic HGV	1,271	1,271	0%	1%	13,996
Buses	26,712	916	9%	0%	22,127
Diesel Train	43	68	0%	0%	6,378
Total	**312,469**	**225,488**	**100%**	**100%**	**2,615,026**

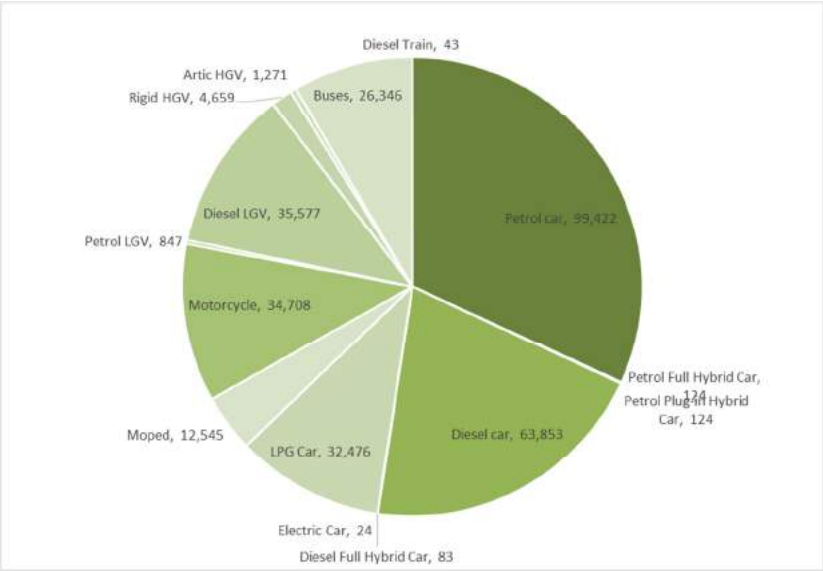

Figure 22. Demand By Vehicle Type

5.2.10 Table 17 provides a comparison between the modelled vehicles and actual fleet figures for Cesena. The figures were provided by Cesena Municipality and cover 2009 to 2011, and have been averaged across all three years. Hybrid vehicles have been included with the non-Hybrid version of the same fuel type (so Petrol-based Hybrids are included with Petrol cars). Electric cars are included in Diesel for this comparison, and represents such a small proportion of vehicles as to make little difference.

5.2.11 Overall, the match is good, with the model underestimating the number of cars and overestimating the number of bikes. Both the number of Private and Goods vehicles are within 1% of the actual totals. Figure 23 shows the comparison graphically.

Table 17. Modelled and Actual Vehicle Comparison

VEHICLE TYPE	AVERAGE ACTUAL (2009-2011)	MODELLED	DIFFERENCE
Population	96,904	96,875	
Petrol Car	30,678	28,712	-1,966
Diesel Car	19,628	18,425	-1,203
Gas Car	9,982	9,355	-627
Cars	60,288	56,492	-3,796
Motorbikes	14,919	18,810	3,891
Goods	7,911	7,853	-59
Total Vehicles	**83,118**	**83,155**	**37**
Cars per person	0.62	0.58	
Bikes per person	0.15	0.19	

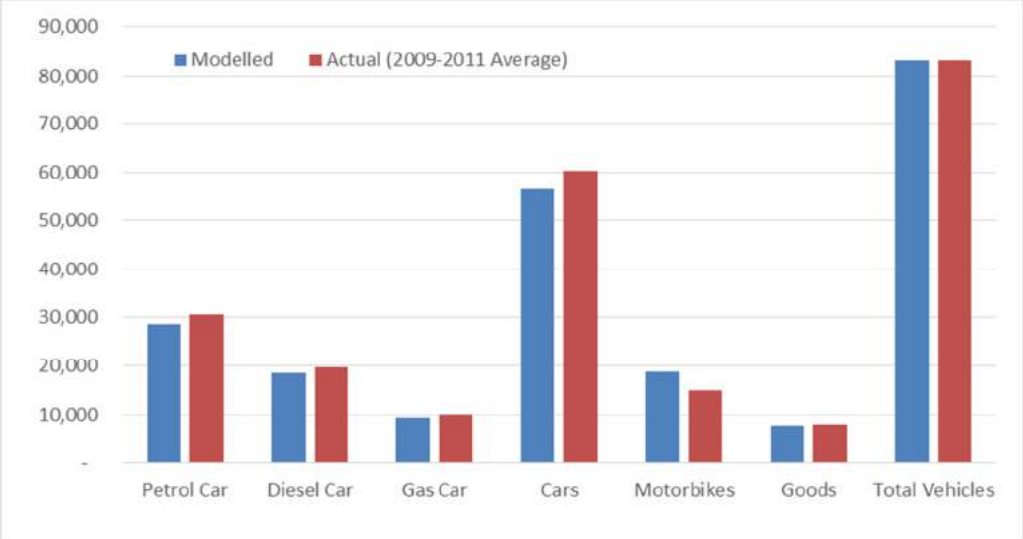

Figure 23. Comparison of Vehicle Totals with Actuals

5.2.12 Figure 24 to Figure 26 show the zone-zone movements for Private Vehicles (Cars and motorbikes), Public Transport and Goods Vehicles.

5.2.13 The Private Vehicles demand is focused on zones 3, 12 and 15 as discussed previously. The PT demand also has a large proportion of demand going to zone 1 which reflects the relative accessibility of that zone via public transport. The goods vehicle demand is focused around large areas of industrial and retail floorspace.

		1	3	14	15	2	4	5	11	12	13	6	7	8	9	10	16		
All Purposes		Centro Urban 2	Fiorenzuola	Cervese Sud 2	Oltre Savio 2	Cesuola	Cervese Sud 1	Oltre Savio1	Ravennate	Dismano	Centro Urban 1	Valle Savio	Borello	Rubicone	Al Mare	Cervese Nord	External	Total	Origin Splits
1	Centro Urban 2	7979	4900	1403	5538	251	334	493	236	687	44	100	0	158	65	12	2604	24804	10%
3	Fiorenzuola	454	12877	2593	2192	167	1300	417	411	1392	22	131	0	1051	242	44	2732	26025	11%
14	Cervese Sud 2	373	4310	4564	2674	133	1309	327	378	1040	17	70	0	261	114	31	1830	17432	7%
15	Oltre Savio 2	872	1917	1420	16403	247	337	1196	303	1326	259	206	1	189	31	15	2899	27621	11%
2	Cesuola	372	2264	1245	2459	656	461	496	350	1196	126	287	1	510	97	30	1237	11787	5%
4	Cervese Sud 1	169	2245	1323	861	58	1370	57	158	437	7	19	0	124	96	31	816	7772	3%
5	Oltre Savio1	351	815	556	4586	115	85	1785	153	993	78	154	1	110	33	7	1152	10975	5%
11	Ravennate	609	2925	1033	3516	293	344	437	706	1112	40	69	1	149	115	76	1340	12767	5%
12	Dismano	442	1320	960	2880	126	308	773	470	3694	55	118	1	139	55	21	1332	12693	5%
13	Centro Urban 1	41	92	99	201	11	32	39	28	95	90	49	0	20	3	2	94	894	0%
6	Valle Savio	597	1103	560	4557	375	139	1051	212	1026	325	1608	26	176	65	13	1388	13222	5%
7	Borello	366	701	318	2104	204	93	494	133	604	161	763	250	121	47	10	747	7115	3%
8	Rubicone	631	4727	727	1287	266	289	249	226	440	24	67	1	2433	241	20	1364	12991	5%
9	Al Mare	537	6274	1325	1209	253	809	362	285	855	26	110	1	814	2472	96	1809	17236	7%
10	Cervese Nord	580	3697	1835	2295	259	1457	369	1107	1783	39	131	1	516	647	419	1775	16909	7%
16	External	1686	5883	2341	6188	400	1016	1002	605	1956	154	455	33	794	507	97	0	23119	9%
	Total	16060	56048	22301	58949	3814	9681	9547	5761	18638	1468	4337	317	7566	4830	923	23119	243360	
	Destination Splits	7%	23%	9%	24%	2%	4%	4%	2%	8%	1%	2%	0%	3%	2%	0%	9%		

Figure 24. Highway Demand

		1	3	14	15	2	4	5	11	12	13	6	7	8	9	10	16		
All Purposes		Centro Urban 2	Fiorenzuola	Cervese Sud 2	Oltre Savio 2	Cesuola	Cervese Sud 1	Oltre Savio1	Ravennate	Dismano	Centro Urban 1	Valle Savio	Borello	Rubicone	Al Mare	Cervese Nord	External	Total	Origin Splits
1	Centro Urban 2	425	193	60	410	10	29	18	1	7	0	0	0	1	0	0	135	1290	5%
3	Fiorenzuola	435	484	78	504	0	3	2	8	3	0	0	0	13	2	0	180	1711	7%
14	Cervese Sud 2	545	267	832	14	1	513	2	32	2	0	0	0	13	0	1	260	2481	10%
15	Oltre Savio 2	670	287	4	1495	13	2	117	0	36	0	3	0	0	0	0	308	2936	12%
2	Cesuola	1297	20	28	1579	48	19	12	4	24	0	2	0	5	1	0	356	3396	14%
4	Cervese Sud 1	444	8	450	14	1	372	1	0	1	0	0	0	0	0	1	152	1445	6%
5	Oltre Savio1	145	3	3	348	0	2	80	0	2	0	0	0	0	0	0	68	652	3%
11	Ravennate	397	486	732	44	3	14	7	257	11	0	1	0	54	1	0	235	2241	9%
12	Dismano	210	13	10	300	1	5	4	1	385	0	1	0	1	0	0	109	1040	4%
13	Centro Urban 1	47	1	2	3	0	2	1	0	2	2	0	0	1	0	0	7	69	0%
6	Valle Savio	171	16	11	317	1	6	5	2	7	0	171	0	2	0	0	83	795	3%
7	Borello	147	16	16	294	1	9	7	3	13	0	126	2	3	1	0	75	713	3%
8	Rubicone	141	214	107	19	1	3	3	20	4	0	1	0	167	0	0	80	761	3%
9	Al Mare	256	373	21	40	1	12	9	3	17	0	2	0	5	187	0	109	1036	4%
10	Cervese Nord	254	37	341	60	4	260	10	5	18	0	2	0	5	1	48	123	1168	5%
16	External	655	283	316	638	10	147	33	40	63	0	36	0	32	23	6	0	2281	9%
	Total	6239	2701	3010	6079	94	1397	313	378	596	4	347	3	302	217	56	2281	24016	
	Destination Splits	26%	11%	13%	25%	0%	6%	1%	2%	2%	0%	1%	0%	1%	1%	0%	9%		

Figure 25. Public Transport Demand

		1	3	14	15	2	4	5	11	12	13	6	7	8	9	10	16		
All Purposes		Centro Urban 2	Fiorenzuola	Cervese Sud 2	Oltre Savio 2	Cesuola	Cervese Sud 1	Oltre Savio1	Ravennate	Dismano	Centro Urban 1	Valle Savio	Borello	Rubicone	Al Mare	Cervese Nord	External	Total	Origin Splits
1	Centro Urban 2	745	731	521	53	1	12	32	21	22	116	7	0	11	4	3	267	2547	6%
3	Fiorenzuola	705	2488	783	46	2	43	30	31	54	128	10	1	66	17	8	517	4929	12%
14	Cervese Sud 2	523	806	1849	82	1	201	54	86	260	89	30	0	105	23	16	484	4610	11%
15	Oltre Savio 2	86	71	115	243	0	49	107	36	293	23	67	0	69	8	5	138	1312	3%
2	Cesuola	4	6	3	0	0	0	0	0	0	1	0	0	0	0	0	2	17	0%
4	Cervese Sud 1	15	46	235	47	0	443	18	63	314	2	21	0	130	32	23	163	1552	4%
5	Oltre Savio1	96	88	121	130	0	24	204	40	453	29	97	0	84	13	5	162	1548	4%
11	Ravennate	73	98	207	54	0	96	46	207	551	20	48	0	113	17	27	183	1741	4%
12	Dismano	27	53	290	265	0	300	325	341	6154	3	294	0	399	58	44	1003	9553	23%
13	Centro Urban 1	260	285	192	28	1	3	18	11	1	407	6	1	2	1	2	143	1361	3%
6	Valle Savio	31	37	102	164	0	58	183	80	782	20	895	0	199	28	13	304	2898	7%
7	Borello	7	8	7	1	0	0	1	0	0	6	1	1	0	0	0	4	36	0%
8	Rubicone	29	125	200	104	0	197	97	112	635	6	119	0	2692	104	29	522	4970	12%
9	Al Mare	14	45	63	18	0	67	20	23	129	2	24	0	148	79	14	76	720	2%
10	Cervese Nord	18	43	65	14	0	56	11	44	120	6	14	0	51	17	22	56	536	1%
16	External	309	578	557	146	1	182	135	128	1146	101	191	1	477	47	25	0	4024	9%
	Total	2942	5507	5308	1395	7	1730	1282	1223	10914	959	1823	5	4549	447	237	4024	42354	
	Destination Splits	7%	13%	13%	3%	0%	4%	3%	3%	26%	2%	4%	0%	11%	1%	1%	9%		

Figure 26. Goods Vehicle Demand

5.2.14 Table 18 shows the public transport boardings by bus and train. On average there is an average occupancy of 27.2 people per vehicle (**Note**: the train demand includes only demand going to/from Cesena and not demand passing through).

Table 18. PT Demand by Vehicle Type

ROUTE NO	BOARDINGS	DAILY SERVICES	AVERAGE OCCUPANCY
Buses	26,712	916	29.2
Trains	43	68	0.6
Total	**26,755**	**984**	**27.2**
PT Demand	24,016		
Average Boardings Per Journey	1.11		

5.3 Energy Outputs

5.3.1 This section covers the Energy Consumption/Usage within Cesena. This includes;

- Total Energy per person, trip and vehicle type;
- Energy by Origin zone; and
- Zone-zone Energy flows.

5.3.2 Table 19 presents a summary of the total energy used by transport within Cesena. The total daily value across all modes, vehicle types, purposes and zones is **7,076,076 MJ**, which is around 73MJ per person, per day.

Table 19. Energy Usage Summary

NO	TOTAL	CARS	BIKES	GOODS	BUSES	TRAINS
Total Energy (MJ)	**7,076,076**	**4,064,280**	**836,511**	**1,884,301**	**174,528**	**116,457**
Population	96,875					
Energy Per Person (MJ)	73.0	42.0	8.6	19.5	1.8	1.2
Demand (Persons)	312,104	196,107	47,253	42,354	26,712	43
Energy Per Trip (MJ)	22.6	20.7	17.7	44.5	6.5	2,720.1
Trips Per Person	3.2	2.0	0.5	0.4	0.3	0.0
Actual Vehicles	84,139	56,493	18,810	7,853	916	68
Energy Per Vehicle (MJ)	84.1	71.9	44.5	240.0	190.5	1,712.6
Vehicles Per Person	0.87	0.58	0.19	0.08	0.01	0.001

Note 1: Energy per Person for Goods demand isn't really meaningful as the demand is not based on residential locations. An increase in population would not necessarily lead to an increase in goods demand in the same way it would with car demand.

5.3.3 Table 20 shows the Energy figures split into Vehicles Types. Unsurprisingly Goods demand use the most energy compared to the number of vehicles – consuming 27% of the total energy from only 9% of the vehicles.

5.3.4 Figure 27 shows the Energy Usage split by Vehicle Type.

Table 20. Energy Consumption (MJ) by Vehicle Type

VEHICLE TYPE	TOTAL ENERGY	% ENERGY	VEHICLES	ENERGY PER VEHICLE
Petrol car	2,091,644	30%	28,640	73
Petrol Full Hybrid Car	1,595	0%	36	45
Petrol Plug-in Hybrid Car	1,535	0%	36	43
Diesel car	1,190,529	17%	18,394	65
Diesel Full Hybrid Car	941	0%	24	39
Electric Car	76	0%	7	11
LPG Car	777,960	11%	9,355	83
Moped	126,942	2%	4,994	25
Motorcycle	709,568	10%	13,816	51
Petrol LGV	28,219	0%	152	186
Diesel LGV	1,055,384	15%	6,383	165
Rigid HGV	546,664	8%	1,035	528
Artic HGV	254,033	4%	282	900
Buses	174,528	2%	916	191
Diesel Train	116,457	2%	68	1,713
Total	**7,076,076**	**100%**	**84,139**	**84**
Cars	4,064,280	57%	56,492	72
Bikes	836,511	12%	18,810	44
Goods	1,884,301	27%	7,853	240
Buses	174,528	2%	916	191
Trains	116,457	2%	68	1,713

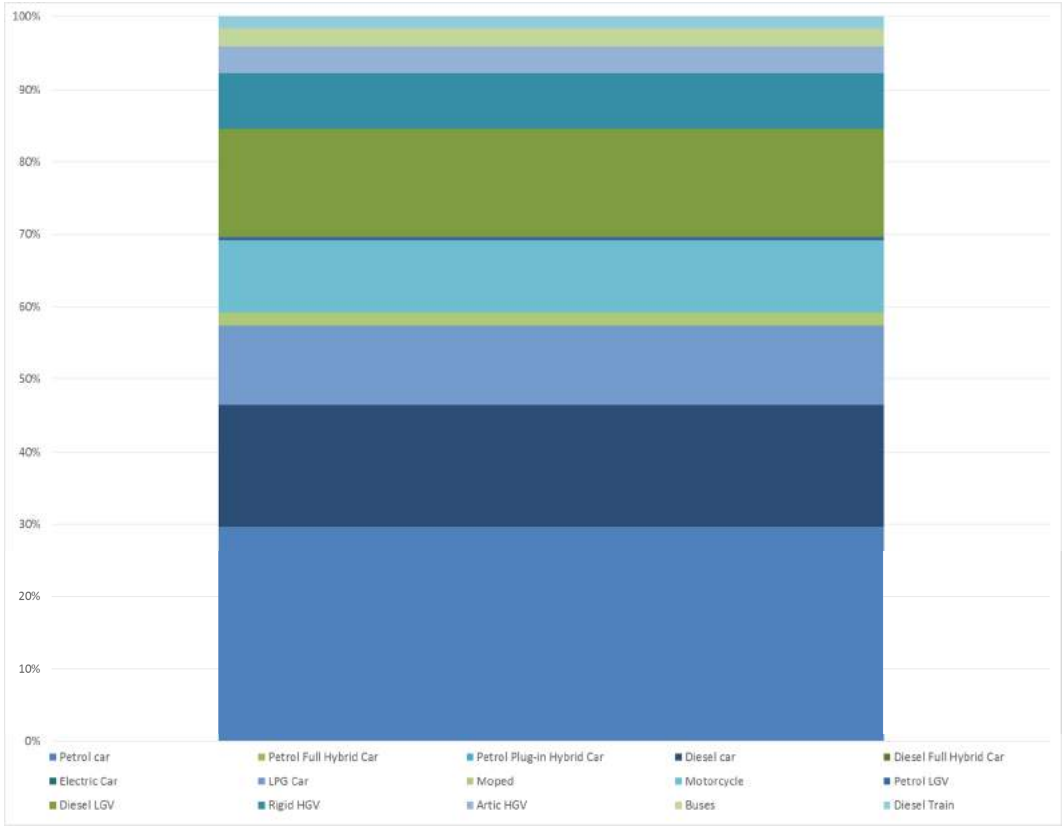

Figure 27. Energy Usage By Vehicle Type

5.3.5 Table 21 shows the Energy Usage split into zones, based on the residential origin of the trip. Figure 28 shows the total energy per zone and Figure 29 shows the energy per person. There are a number effects present here;

- Zones further out consume more energy due to the distance they have to travel, primarily to central zones. Looking at energy per person and trips at an Area Type level, there is a steady increase in these values as you move further from the centre.
- Zones with a low population consume little energy – for example zone 13. The zones with a higher population are generally closer to the centre of the city so the extra energy used by the additional people is offset by the shorter distances they have to travel.
- The plot of Energy Usage per Person highlights the relationship between energy usage and distance.

Table 21. Energy Per Zone – Private Vehicles Only

NO	ZONE NAME	AREA TYPE	POP	DEMAND	ENERGY (MJ)	ENERGY/ PERSON	ENERGY /TRIP
1	Centro Urban 2	1	11,421	18,818	258,072	22.6	13.7
3	Fiorenzuola	2	10,745	20,498	328,356	30.6	16.0
14	Cervese Sud 2	2	9,170	13,837	218,383	23.8	15.8
15	Oltre Savio 2	2	14,406	21,030	314,758	21.8	15.0
2	Cesuola	3	5,089	9,686	217,588	42.8	22.5
4	Cervese Sud 1	3	4,255	6,124	103,966	24.4	17.0
5	Oltre Savio1	3	4,650	8,406	161,013	34.6	19.2
11	Ravennate	3	5,347	9,508	221,446	41.4	23.3
12	Dismano	3	4,637	10,118	220,196	47.5	21.8
13	Centro Urban 1	3	310	758	14,863	47.9	19.6
6	Valle Savio	4	5,671	10,154	278,060	49.0	27.4
7	Borello	4	2,766	5,475	189,035	68.3	34.5
8	Rubicone	4	5,082	10,035	238,219	46.9	23.7
9	Al Mare	4	6,825	13,237	302,887	44.4	22.9
10	Cervese Nord	4	6,501	13,513	380,141	58.5	28.1
16	External	4	-	17,970	1,453,809	-	80.9
	Total (inc External)			**189,167**	**4,900,791**	**-**	**25.9**
	Total (exl External)		**96,875**	**171,197**	**3,446,982**	**35.6**	**20.1**

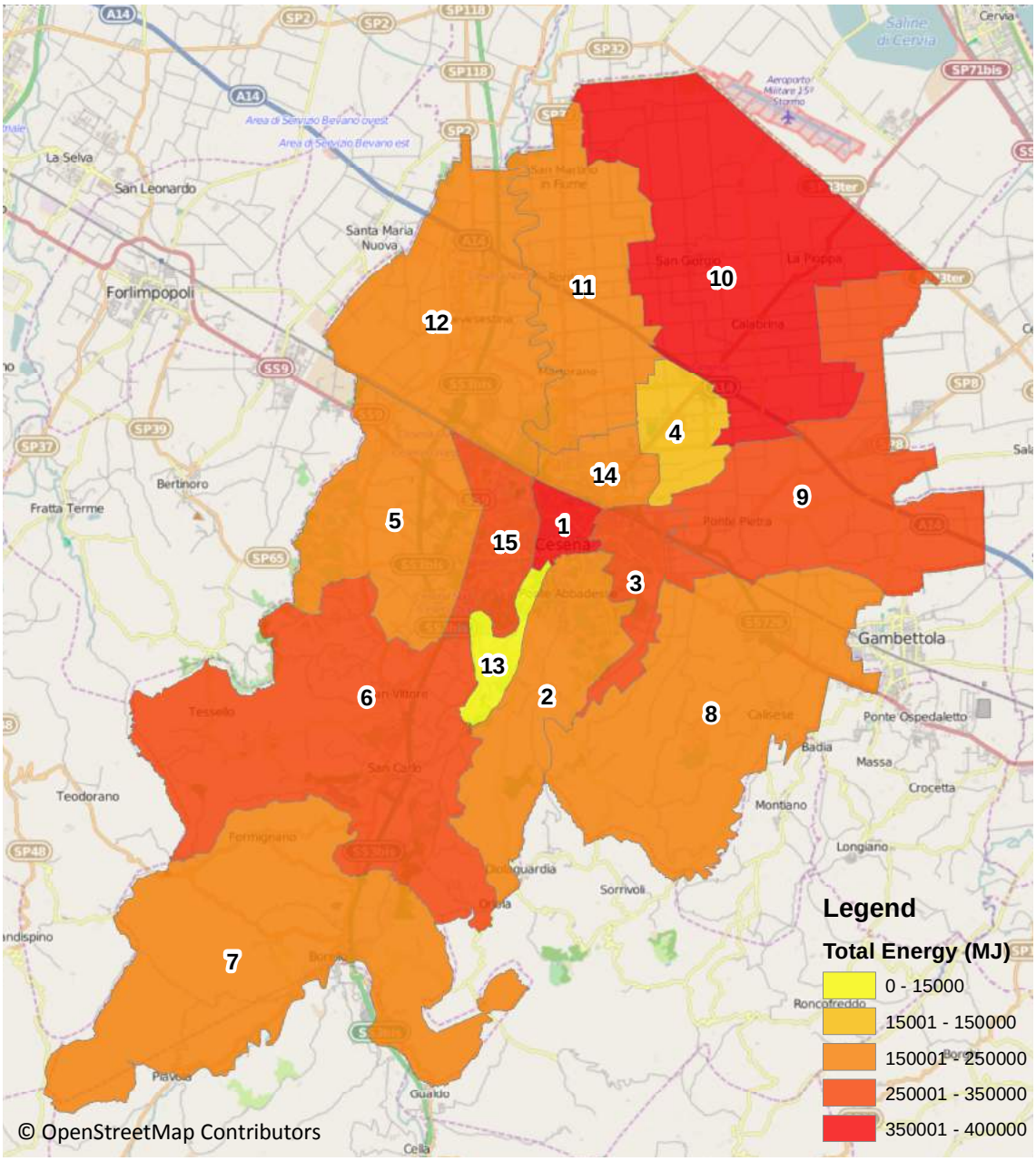

Figure 28. Total Energy (MJ) Per Origin Zone

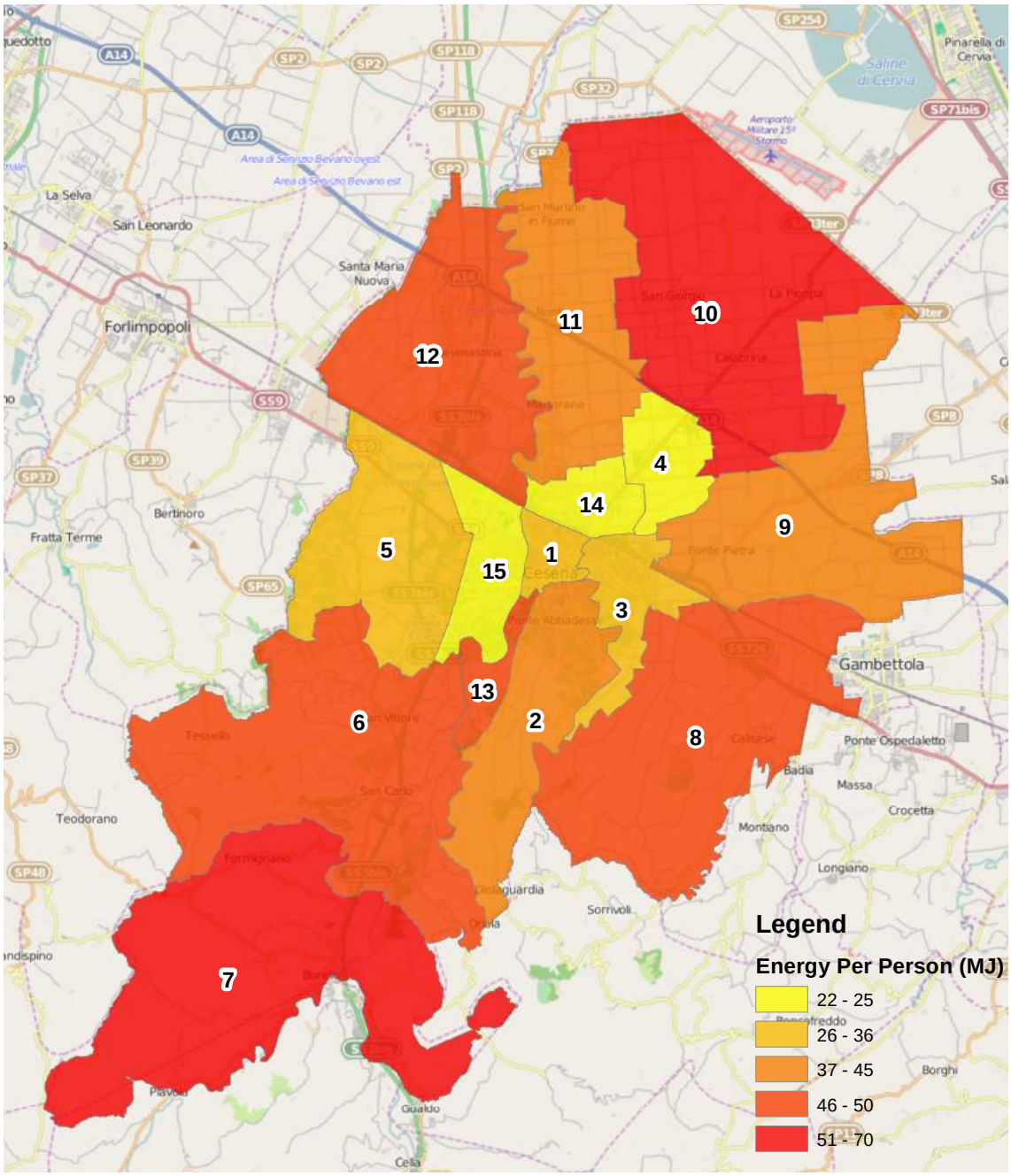

Figure 29. Energy (MJ) per Population

5.3.6 Table 22 to Table 24 show the zone-zone energy usage flows. The highway and goods matrices are similar to the demand matrices.

5.3.7 However, the Public Transport energy is calculated on the basis of the actual vehicles serving the routes, rather than the demand. They are then allocated based on the start and end zone of each service. Hence, the majority of the PT energy is to/from zone 1 which is where most routes start or end.

Table 22. Zonal Energy Usage – Private Vehicles

	Private Vehicles	Centro Urban 2	Fiorenzuola	Cervese Sud 2	Oltre Savio 2	Cesuola	Cervese Sud 1	Oltre Savio1	Ravennate	Dismano	Centro Urban 1	Valle Savio	Borello	Rubicone	Al Mare	Cervese Nord	External	Total	Origin Splits
		1	3	14	15	2	4	5	11	12	13	6	7	8	9	10	16		
1	Centro Urban 2	22276	20336	7470	23395	1627	2888	3693	2597	9123	290	1548	6	2516	724	207	159378	258,072	5%
3	Fiorenzuola	2340	45304	18815	18687	1305	10812	6020	6312	23998	217	3277	4	12224	2375	732	175934	328,356	7%
14	Cervese Sud 2	1882	23896	17721	19075	1229	7270	3881	4033	13745	166	1604	6	4005	1250	418	118202	218,383	4%
15	Oltre Savio 2	4532	15077	12085	57908	2021	4105	8070	4329	17157	1842	3038	15	3674	618	319	179967	314,758	6%
2	Cesuola	3144	20590	15879	23589	4008	7600	7249	6515	24878	1351	5490	17	9661	1670	706	85241	217,588	4%
4	Cervese Sud 1	1347	14387	7354	8467	693	5595	1258	1984	6418	91	619	3	2015	946	322	52469	103,966	2%
5	Oltre Savio1	2945	10251	7420	30197	1361	2076	10556	2855	13015	892	2370	22	2553	635	205	73658	161,013	3%
11	Ravennate	6138	35789	10983	41149	4124	4207	6637	6057	14595	623	1755	35	3211	2009	888	83242	221,446	5%
12	Dismano	5733	19267	13235	32321	2079	4832	8907	6608	29133	904	2561	34	3551	1142	445	89444	220,196	4%
13	Centro Urban 1	289	889	1067	1476	105	458	470	459	1673	380	552	2	442	67	37	6496	14,863	0%
6	Valle Savio	9035	23071	13478	59201	5772	4909	14817	6106	23460	3728	15701	315	5868	1793	512	90295	278,060	6%
7	Borello	7863	18762	10014	39996	4321	3976	10155	4819	18269	2474	10829	1555	4918	1598	443	49043	189,035	4%
8	Rubicone	10159	48964	11990	21912	4148	5147	5321	5365	11561	481	2203	21	17900	3149	477	89422	238,219	5%
9	Al Mare	6553	57043	18015	22852	3624	10239	7430	6477	21273	501	3522	22	12514	14778	1367	116677	302,887	6%
10	Cervese Nord	10064	53608	28544	43614	4856	18232	10114	16330	41426	878	5139	38	13134	8436	4227	121503	380,141	8%
16	External	104814	339484	163628	364404	22990	71897	64957	44388	141033	9740	31199	1937	56185	30574	6579	0	1,453,809	30%
	Total	199,114	746,716	357,698	808,246	64,265	164,243	169,536	125,235	410,756	24,556	91,407	4,032	154,371	71,763	17,884	1,490,970	4,900,791	
	Destination Splits	4%	15%	7%	16%	1%	3%	3%	3%	8%	1%	2%	0%	3%	1%	0%	30%		

Table 23. Zonal Energy Usage – Goods Vehicles

	Goods Vehicles	Centro Urban 2	Fiorenzuola	Cervese Sud 2	Oltre Savio 2	Cesuola	Cervese Sud 1	Oltre Savio1	Ravennate	Dismano	Centro Urban 1	Valle Savio	Borello	Rubicone	Al Mare	Cervese Nord	External	Total	Origin Splits
		1	3	14	15	2	4	5	11	12	13	6	7	8	9	10	16		
1	Centro Urban 2	5078	7704	5720	567	21	210	539	463	630	1734	229	21	369	107	106	34979	58,477	3%
3	Fiorenzuola	7935	21265	10983	880	41	722	879	913	1948	2792	523	33	1593	353	272	68397	119,531	6%
14	Cervese Sud 2	6006	11109	14738	1490	24	2392	1425	1856	7241	1952	1447	27	3400	614	457	65198	119,375	6%
15	Oltre Savio 2	979	1348	2097	2228	5	1248	1669	1073	7981	362	2114	6	2835	376	241	19308	43,868	2%
2	Cesuola	71	132	79	8	1	1	7	6	1	31	2	1	3	2	2	249	594	0%
4	Cervese Sud 1	272	770	2836	1197	1	4049	862	1646	9749	58	1496	1	4519	794	539	23240	52,029	3%
5	Oltre Savio1	1817	2641	3351	2232	8	1236	2967	1551	12602	755	3239	12	4120	589	331	23190	60,640	3%
11	Ravennate	1769	3042	4812	1737	8	2692	1809	3787	16298	686	2801	10	5567	790	793	26278	72,879	4%
12	Dismano	818	1980	8725	7772	1	9942	9165	10147	106990	104	14038	2	21774	3013	2090	146720	343,280	18%
13	Centro Urban 1	3929	6089	4154	425	21	73	433	342	39	3805	130	32	104	41	87	18726	38,429	2%
6	Valle Savio	1108	1957	5198	5617	5	4284	6368	4760	38077	506	20526	12	14247	1963	1100	45120	150,848	8%
7	Borello	331	516	413	47	3	6	48	34	5	214	19	17	14	13	10	520	2,210	0%
8	Rubicone	1039	3288	7030	4558	4	7442	4859	5603	35132	269	8458	5	45857	3535	1589	76836	205,502	11%
9	Al Mare	378	1031	1781	840	2	1796	952	1093	6756	83	1613	3	4940	1237	449	10954	33,909	2%
10	Cervese Nord	696	1544	2080	694	4	1507	680	1365	5891	295	1146	5	2779	564	515	8276	28,041	1%
16	External	40043	75326	74333	20353	102	25592	18885	18120	162996	13067	27485	74	68114	6639	3561	0	554,692	29%
	Total	72,269	139,742	148,329	50,644	250	63,191	51,547	52,759	412,336	26,714	85,266	260	180,231	20,630	12,141	567,992	1,884,301	
	Destination Splits	4%	7%	8%	3%	0%	3%	3%	3%	22%	1%	5%	0%	10%	1%	1%	30%		

Table 24. Zonal Energy Usage – Public Transport

	All PT	Centro Urban 2	Fiorenzuola	Cervese Sud 2	Oltre Savio 2	Cesuola	Cervese Sud 1	Oltre Savio1	Ravennate	Dismano	Centro Urban 1	Valle Savio	Borello	Rubicone	Al Mare	Cervese Nord	External	Total	Origin Splits
		1	3	14	15	2	4	5	11	12	13	6	7	8	9	10	16		
1	Centro Urban 2	-	-	-	-	1,418	1,070	200	-	1,473	28	-	2,495	-	-	1,939	126,105	134,729	46%
3	Fiorenzuola	-	-	-	3,675	-	-	-	-	-	-	-	-	-	-	-	-	3,675	1%
14	Cervese Sud 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
15	Oltre Savio 2	-	3,675	-	-	3,015	-	-	-	-	-	-	-	-	-	-	-	6,690	2%
2	Cesuola	1,418	-	-	3,056	-	-	-	-	-	-	-	-	-	-	-	-	4,474	2%
4	Cervese Sud 1	1,070	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,070	0%
5	Oltre Savio1	133	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	133	0%
11	Ravennate	-	-	-	-	-	-	-	-	-	-	-	-	2,592	-	-	-	2,592	1%
12	Dismano	1,381	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,381	0%
13	Centro Urban 1	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	0%
6	Valle Savio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
7	Borello	2,620	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,620	1%
8	Rubicone	-	-	-	-	-	-	-	2,268	-	-	-	-	-	-	-	-	2,268	1%
9	Al Mare	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%
10	Cervese Nord	2,108	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,108	1%
16	External	129,216	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	129,216	44%
	Total	137,975	3,675	-	6,731	4,434	1,070	200	2,268	1,473	28	-	2,495	2,592	-	1,939	126,105	290,985	
	Destination Splits	47%	1%	0%	2%	2%	0%	0%	1%	1%	0%	0%	1%	1%	0%	1%	43%		

5.3.8 Table 25 shows the energy usage for buses and trains within Cesena, including energy per passenger and per vehicle km.

Table 25. PT Energy Usage By Vehicle Type

ROUTE NO	TOTAL ENERGY	SERVICES	ROUTE LENGTH (KM)	VEHICLE KMS	ENERGY/ VEHKMS	ENERGY/ PASS
Buses	174,528	916	385.3	22,127	7.89	6.53
Train	116,457	68	93.8	6,378	18.26	2708.30
Total	**290,985**	**984**	**479.1**	**28,505**	**10.21**	**10.88**

5.4 Emissions Outputs

5.4.1 This section of the report looks at other emissions calculated by the model. These include;

- Nitrous Oxides;
- Particulate Matter (PM10s);
- Hydro Carbons;
- Carbon Monoxide; and
- Carbon Dioxide.

5.4.2 Figure 27 shows the Carbon Dioxide Emissions split into Vehicle Type. These splits are very similar to the Energy Usage splits.

5.4.3 Figure 28 shows the Vehicle Type splits for the other Emissions types. It can be seen that the splits here are very different to the Carbon Dioxide splits, shown on the far right. Mopeds and Motorbikes are more responsible for Hydro-Carbons, PM10s and Carbon Monoxide.

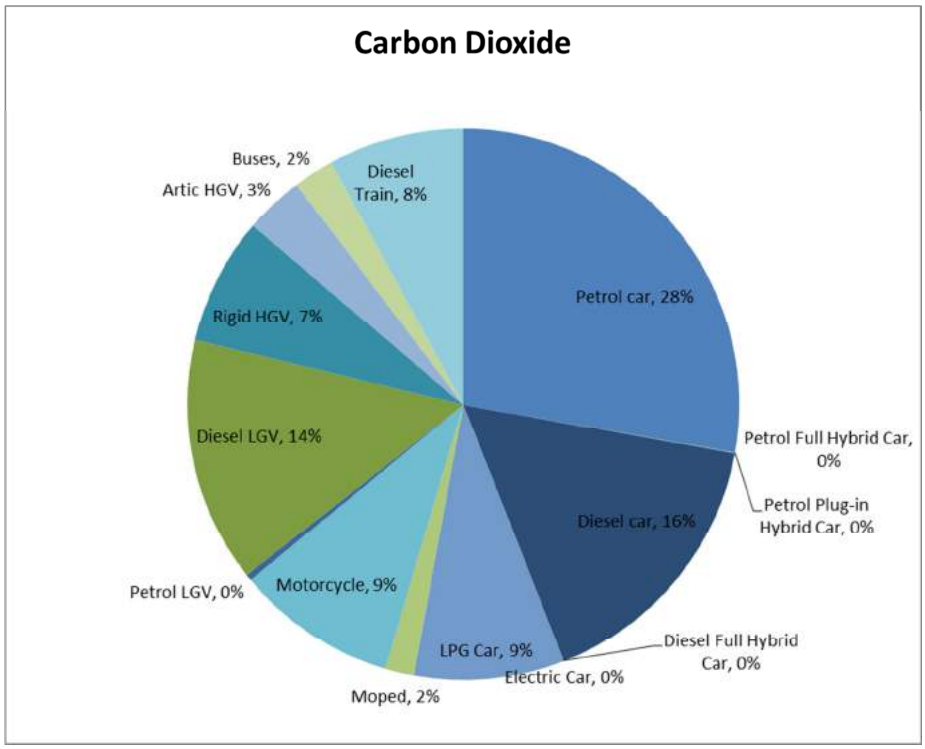

Figure 30. Carbon Dioxide Emissions By Vehicle Type

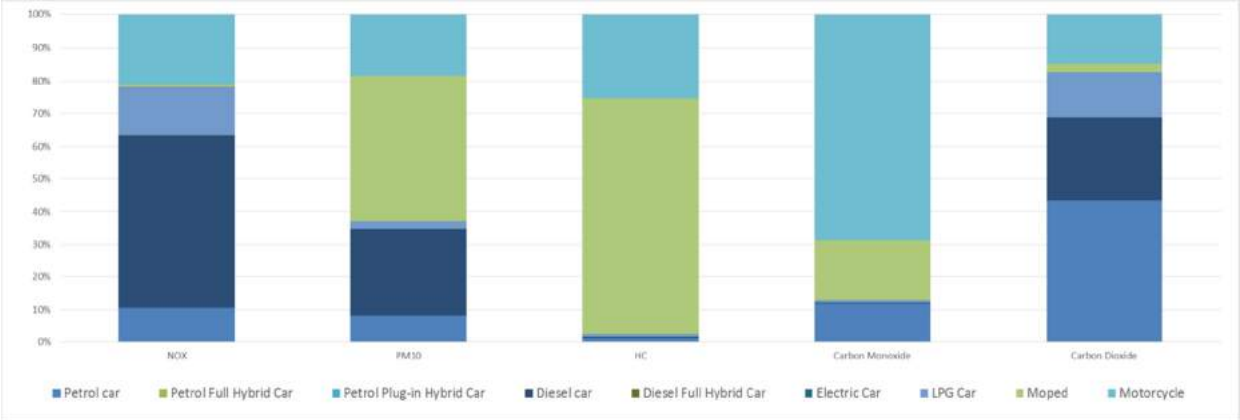

Figure 31. Emissions by Vehicle Type

Table 26. Emissions By Vehicle Type (Kg)

VEHICLE TYPE	NOX	PM10	HCS	CO	CO2
Petrol car	44	3	14	675	153,818
Petrol Full Hybrid Car	0	0	0	1	117
Petrol Plug-in Hybrid Car	0	0	0	1	113
Diesel car	221	9	11	24	89,800
Diesel Full Hybrid Car	0	0	0	0	71
Electric Car	-	-	-	-	-
LPG Car	61	1	10	31	48,652
Moped	4	15	911	1,033	9,335
Motorcycle	88	6	322	3,876	52,181
Petrol LGV	1	0	0	19	2,075
Diesel LGV	161	8	12	63	79,607
Rigid HGV	177	3	5	28	41,234
Artic HGV	84	1	2	8	19,161
Buses	61	1	2	6	13,164
Diesel Train	-	-	-	-	44,030
Total	**902**	**45**	**1,290**	**5,765**	**553,360**
Cars	327	12	36	731	292,572
Bikes	92	21	1,233	4,909	61,516
Goods	423	11	19	118	142,078
Buses	61	1	2	6	13,164
Trains	-	-	-	-	44,030