Four Stage Model

What is the four stage model

The four stage model (FSM) is the primary tool for forecasting demand and performance of a transportation system, typically defined at a regional or sub-regional scale.

The FSM must be suitably policy sensitive to allow for the comparison of alternative interventions to influence future demand and performance. The models system was developed for evaluating large-scale infrastructure projects, not for subtle and complex policies involving the management and control of existing infrastructure or the introduction of policies that directly influence travel behaviour. For example the construction of a LRT network compared to a car pool scheme.

Application of travel forecasting models is a continuous process. The period required for data collection, model estimation, and subsequent forecasting exercises may take years during which time the activity and transportation systems change, as do policies of interest, often requiring new data collection efforts and new modelling effort.

Study area definition

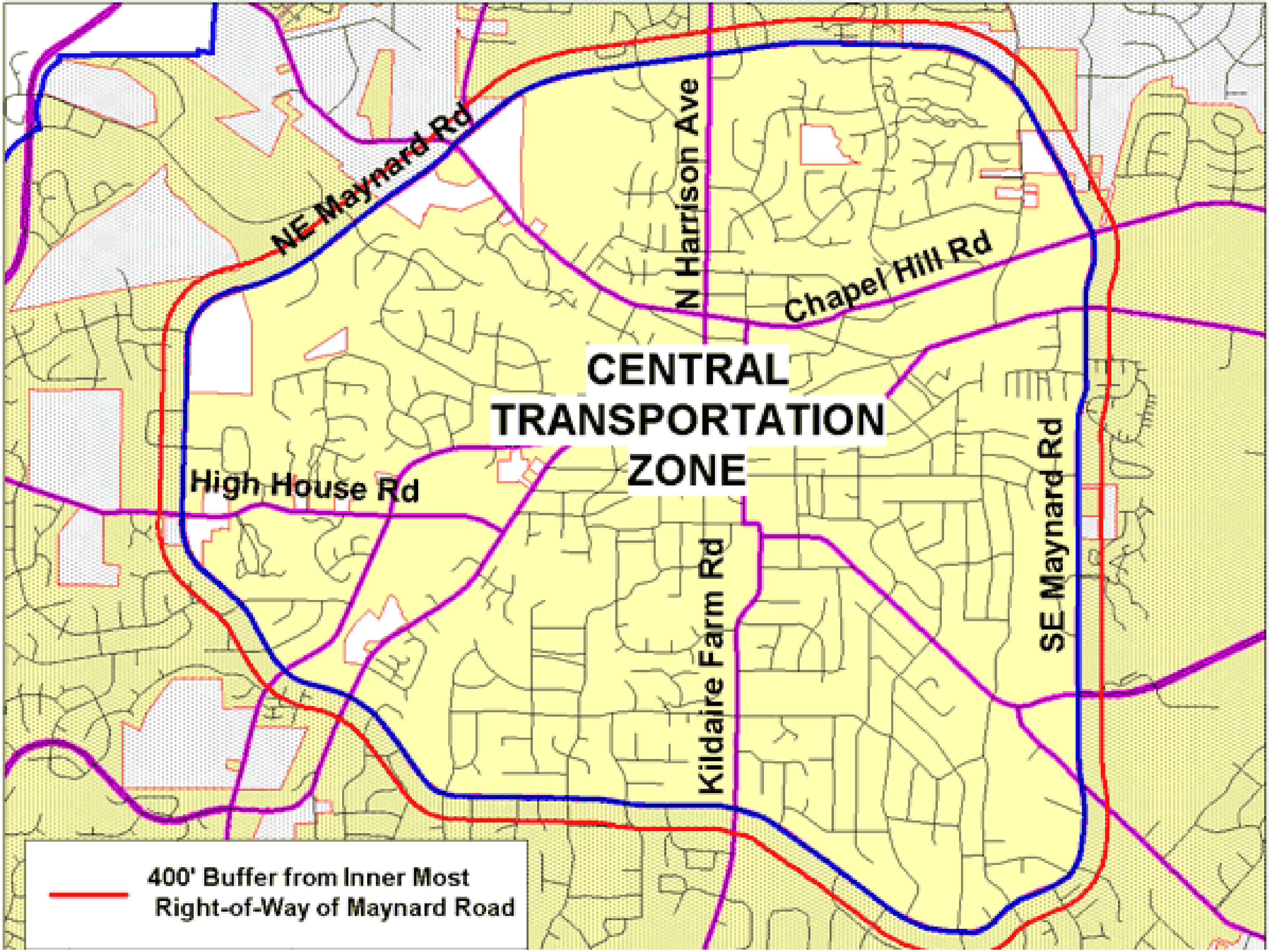
Once the nature of the problem at hand has been identified, the study area can be defined to encompass the area of expected policy impact; a cordon line defines this area. In Dublin this has traditionally been called the canal cordon. The area within the cordon is composed of traffic analysis zones (TAZs) and is subject to explicit modelling and analysis. Interaction with areas outside the cordon is defined via external stations which effectively serve as doorways for trips into, out of, and through the study area. The internal activity system A is typically represented by socio-economic, demographic, and land-use data defined for TAZs or other convenient spatial units.

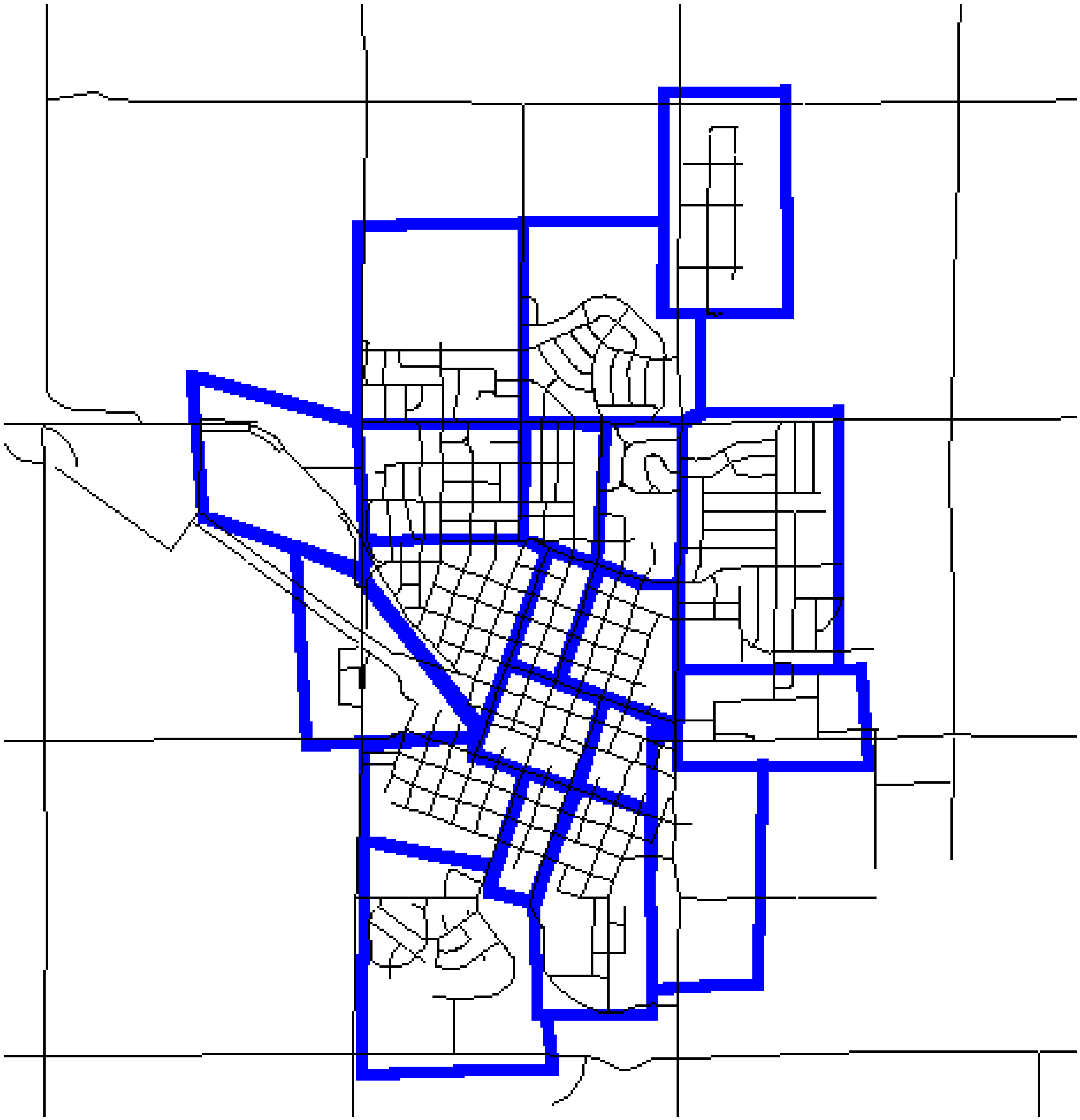
The number of TAZs, based on model purpose, data availability, and model vintage, can vary significantly (from several hundred to several thousand). The unit of analysis, however, varies over stages of the FSM, and might be at a level of individual persons, households, TAZ's, or some larger aggregation.

Transport Network

The transportation system T is typically represented via a network graphs defined by links (one-way sections of transportation infrastructure or service) and nodes (link endpoints, typically intersections or points representing changes in link attributes). Both links and nodes have associated attributes (length, speed, capacity, turning prohibitions).

An activity system A is interfaced with the transportation system T via centroid connectors, which are links connecting TAZ centroids to realistic access points on the physical network.


NE Maynard Rd
N Harrison Ave
Chapel Hill Rd
CENTRAL
TRANSPORTATION
ZONE
High House Rd
Kildaire Farm Rd
SE Maynard Rd
400' Buffer from Inner Most
Right-of-Way of Maynard Road



Trip Generation

Trip Distribution

Modal Split

Trip Assignment

Trip Generation

Trip Generation

The objective of the first stage if the FSM is to define the magnitude of daily travel in a model system, at the household and zonal levels, for various trip purposes (activities).

This first stage also explicitly translates the FSM from being an activity based to being trip based, and simultaneously serves each trip into a production and attraction, effectively preventing network performance measures from influencing the frequency of travel.

Generation essentially defines total travel time in the region and the remaining steps are effectively share models.

Relate the total number of trip origins and destination to one zone and zonal characteristics.

Assumption:

The relationships developed for the model remain the same for the future and so if land-use and socio-economic factors can be predicted, future trips can be estimated for any proposed transport system.

Definitions:

- A trip is a one-way person movement with an origin and a destination (O-D)
- Trips which have one end at home are said to be generated by the home
- For non-home-based trips the zone of the origin is said to generate the trip and the zone of destination is said to attract the trip
- A car available trip is any trip where the trip maker has the choice of travelling by car or an alternative mode
- A non-car-available trip is any trip where the trip maker does not have travelling by car as part of their choice

Means of performing trip generation:

1. Allocate trips to transport modes before the distribution of trips between traffic zones (trip ends)
2. The trips may be distributed between the zones before the decision is made regarding the mode of travel

Trip Generation Equations

Dependent variable = no. of trips generated per person per household for different trip purposes

Independent variables = land use and socio-economic factors which are considered to influence trip making

Land-use

Densely population residential areas will generate large numbers of trips in the morning peak period.

Industrialised areas will attract large numbers of trips in the morning peak.

Other factors which could influence trip generation are:

- Family size
- Income
- Car availability
- Social status

Trip chaining

Trip chaining is a term used to describe the combination of trip purposes on one trip.

Zonal least squares regression analysis:

The dependent variable (the number of trip ends) is related to the independent characteristics which can be measured.

The equation developed is typically of the form

$$Y = b_0 + b_1X_1 + b_2X_2 + \dots\dots\dots + b_nX_n$$

Where: Y is the dependent variable

b, are the values obtained by the regression analysis

X are the independent variables

Assumptions

1. All independent variables are independent of each other
2. All independent variables are normally distributed
3. The independent variables are continuous

Sources of error in regression analysis

- Determination of base year values of the independent variables due to bias or inaccuracy in the survey
- Errors in determination of the base year values of the dependent variables
- Assumption that the regression of the dependent variable is linear with respect to the independent variable
- Errors due to the inadequacy of the data
- Independent variables which may influence trip making in the future may not exist in the base year (e.g. introduction of a Metro Line)

Checks for errors

- Simple correlation coefficient r which measures the association between two variables
- Multiple correlation coefficient R^2 which measures the goodness of fit between the regression estimates and the data

A typical regression equation was

$$Y_8 = 0.0649\ X_1 - 0.0034\ X_3 + 0.0066\ X_4 + 0.9489\ Y_1$$

Where Y_8 = total trips per household / 24hr where the head of the household is a junior manual worker

X_1 = family size

X_3 = residential density

X_4 = total family income

Y_1= cars/household

Category Analysis

Disaggregating to the household level.

More flexible than other regression methods.

Household is the fundamental unit of trip generation process.

Assumption: that the journeys the household generates depend on household characteristics and location relative to the workplace etc.

Household characteristics:

- Disposable income
- Car ownership
- Family structure
- Family size

Household classifications:

- **Car owned:** none, 1, more than 1
- **Income:** use census guidelines
- **Family structure:** number of adults employed
- **Mode of transport:** by trip purpose

Assumptions for category analysis:

- Trip rate will remain stable over time for a particular household class
- The behaviour of a household can be described by the category into which it falls

Income Distribution

A continuous probability density function is used to distribute income.

Future incomes are projected on the basis of an annual growth factor.

Car ownership

An example of car ownership is: $P(0/x) = Ke^{-bx}$

$P(1/x) = Ce^{-Bx}(Bx)^n$

P(0/x) is the prob of not owning a car

P(1/x) prob of owning a car

X is the income of the household relative to the price of cars

K and C are constants

B varies with bus accessibility

Trip generation in the NTA Model

The trip generation stage of the NTA four stage model uses a Trip Attraction and Generation Model (TAGM).

The first stage od this model is to estimate the all-day trip rates in the GDA. The model uses the following datasets to estimate this:

- 2006 Census travel to work data (POWCAR),
- 2006 GDA travel to education survey,
- 2006 GDA household survey,
- 2006 CSO small area population statistics (SAPS)

To calculate the trip generation rates for each zone the trips are classified by the following (home-based) trip purposes:

- Work
- Education
- Retail
- Other (all other personal trips)
- Business trips

In addition to estimating the trips for the population within each zone, the model also calculates the trip rates for various sub-groups

Employment group

- Full time
- Part time
- Retired
- Other (unemployed)

Socio-economic group (SEG)

- SEG1: Employers & Managers, higher and lower professionals
- SEG 2: Manual Skilled, Semi-skilled manual, unskilled
- SEG 3: Farmers and agricultural workers and all others

Car availability

- car available
- car not available

Trip generators

A ‘planning sheet’ is used as the main input from the forecast year (an example is shown on the next slide).

18 predictive land use variables are used and modelled in 657 zones. The most important travel demand factors are:

- Population (segmented by employment and SEG)
- Employment (number of jobs in each zone)
- Education (Schools, IOT’s and Universities)
- Retail floor space

Figure 4 – section of the "Planning Sheet" – the main input to the TAGM

Model Zone	Zone Name	Zone Area	O_Area Type	D_Area Type	Pop Total	SEG1 %	SEG2 %	SEG3 %	Emp FullTime	Emp PartTime	Retired
1	11101	143090	22	4	1,761	55.66	32.97	11.37	836.99	157.50	224.47
2	11103	2404723	20	8	38	46.33	40.10	13.58	16.65	2.74	3.83
3	11104	392480	22	1	596	46.33	40.10	13.58	261.33	42.88	60.07
4	11105	587195	22	3	5,722	58.25	31.15	10.60	2508.64	411.57	576.69
5	11106	379102	22	1	4,607	58.25	31.15	10.60	2022.47	331.95	464.80
6	13101	76494	31	6	879	33.51	42.90	23.58	324.24	89.75	50.23
7	13102	84536	31	5	1,252	33.51	42.90	23.58	461.72	127.80	71.53
8	13103	138069	31	1	1,867	33.51	42.90	23.58	689.13	190.74	106.75
9	13111	118605	31	1	1,683	35.86	46.20	17.94	754.72	115.53	78.62
10	13112	105131	31	1	2,322	35.86	46.20	17.94	1041.37	159.41	108.48
11	13121	42856	21	1	924	59.50	28.73	11.77	512.51	57.45	48.96
12	13122	86847	21	1	377	46.25	36.69	17.06	209.20	23.45	19.98
13	13123	118184	21	1	1,110	59.50	28.73	11.77	615.87	69.03	58.83
14	13124	126467	21	1	1,253	59.50	28.73	11.77	695.19	77.93	66.42

Car Ownership / Car Availability Model

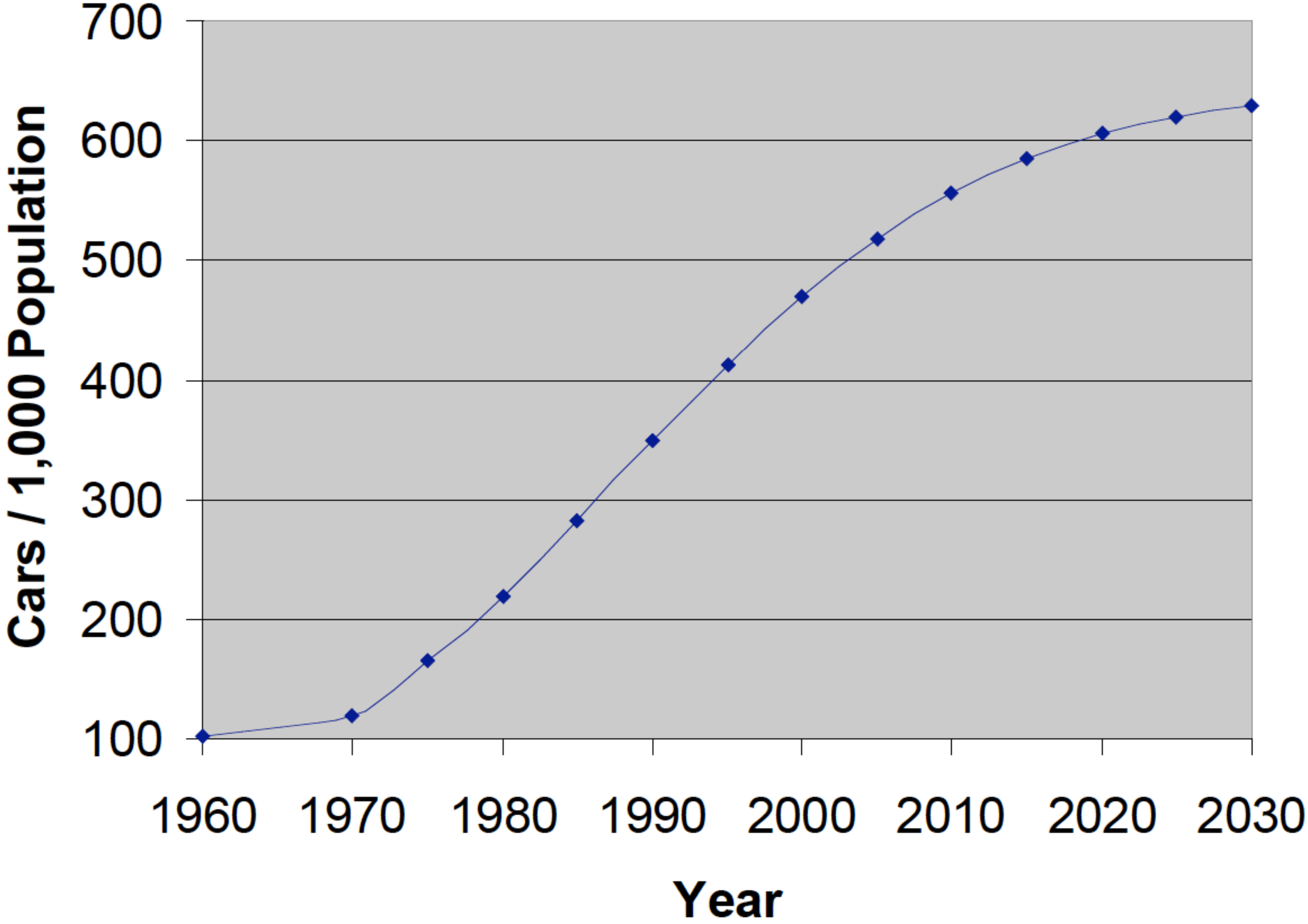
Car availability had a significant impact upon an individuals travel behaviour. Car available and car not available segments are used in each zone for the TAGM – this is called the COM (car ownership model).

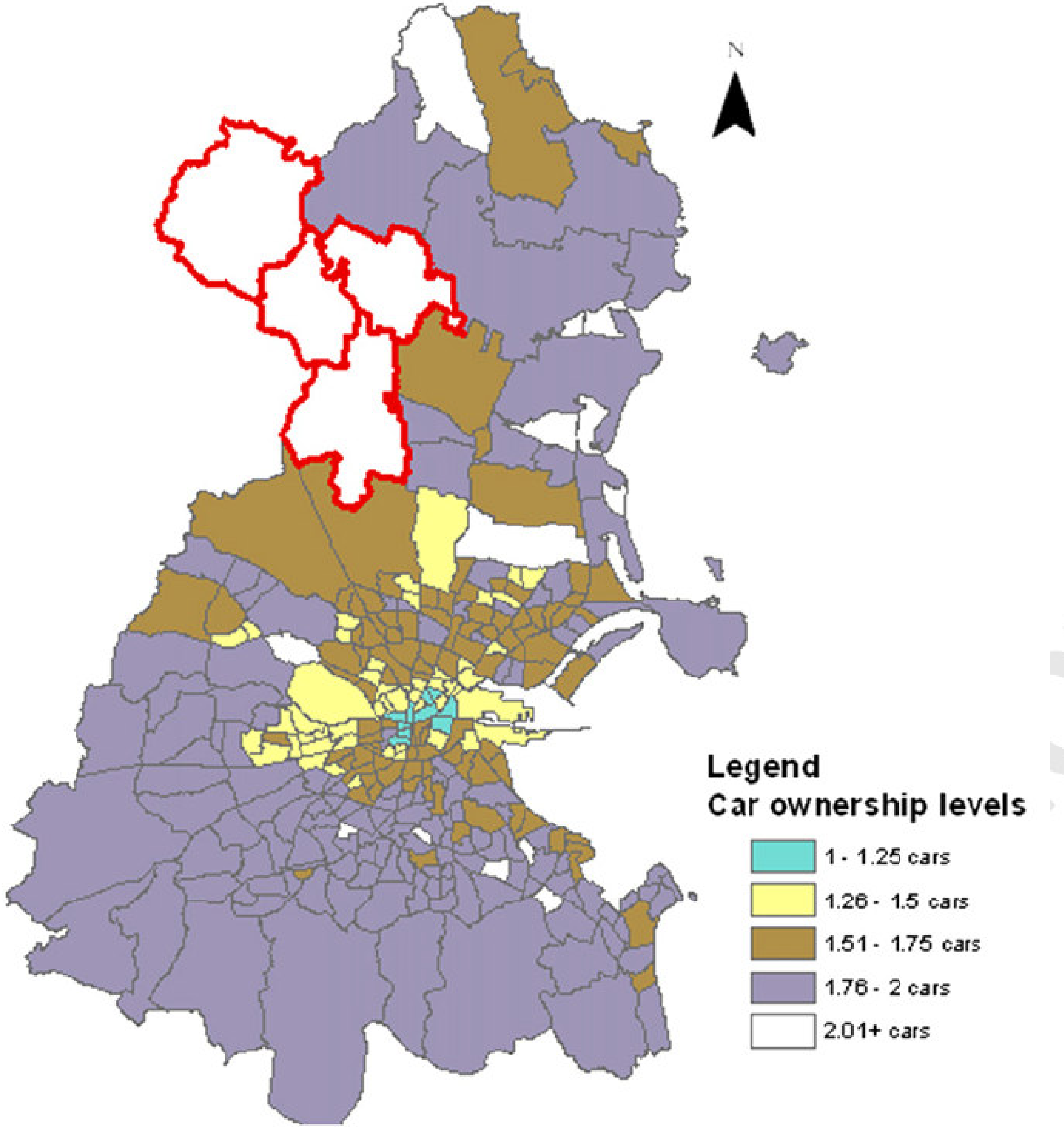
The purpose of this model is twofold:
- track and predict growth in car ownership over time
- determine the probability of people in the zone having a car available for a trip

In predicting car ownership, the COM employs the standard form of car ownership S-curve. The curve shows vehicle density (expressed as the number of cars owned per 1,000 population) on the Y-axis, plotted against time in years on the X-axis.

The S-curve shows three distinct regions as car ownership levels rise over time – very low levels at the start, rapid growth as people's wealth increases, and finally a levelling off of car ownership as the number of cars owned reaches saturation levels.

Car Ownership S-Curve




N
Legend
Car ownership levels
1 - 1.25 cars
1.26 - 1.5 cars
1.51 - 1.75 cars
1.76 - 2 cars
2.01+ cars

Trip Generation Examples

Example 1

A simple linear regression model is estimated for shopping-trip generation during a shopping-trip peak hour (e.g. Saturday afternoon). The model is

Number of peak-hour vehicle-based shopping trips per-household =

0.12+0.09(HH size) + 0.011 (annual HH income in €000s) – 0.12 (retail employment in HH neighbourhood – in 100’s)

A particular HH has 6 members and annual income of €50,000. they live in a neighbourhood with 450 retail employees.

They move to a new home in a neighbourhood with 150 retail employees.

Calculate the predicted no. of vehicle based peak-hour shopping trips the HH makes after the move.

Solution:

Note signs of coefficients; +0.09 and +0.011 indicate that as HH size and income increase, the no. of shopping trips also increase

The negative sign of the employment coefficient (-0.15) indicates that as retail employment in the HH neighbourhood increases, fewer vehicle-based shopping trips will be generated. (large retail employment in the area implies more shopping opportunities nearer a HH, thereby increasing the possibility that shopping trips may be made without the use of a vehicle)

<u>Before:</u>

No. vehicle trips = 0.12+0.09(6)+0.011(50)-0.15(4.5) = 0.535

<u>After:</u>

No. vehicle trips = 0.12+0.09(6)+0.011(50)-0.15(1.5) = 0.985

Therefore this model predicts that the move will result in 0.45 additional peak-hour vehicle based shopping trips.

Example 2

A model for social/recreational trip generation in estimated, with data collected during a major holiday, as:

Number of peak-hour vehicle-based social/recreational trips per HH =

0.04+0.018 (HH size) + 0.009 (annual HH income) + 0.16 (no. of non-working HH members)

If the family described in example 1 has one working member, how many peak-hour social/recreational trips are generated?

Solution:

Note the + signs of the coefficients (as the values of the variables are increased the no. of trips also increases).

The more non-working HH members the larger the no. of people available at home to make peak-hour social/recreational trips.

No of vehicle trips = 0.04+0.018(6) + 0.009 (50) + 0.16(5) = 1.398

Example 3

A neighbourhood has a retail employment of 205 and 700 HH that can be categorised into 4 types, each type having the same characteristics as follows:

Type	HH size	Annual Income	No. of non-workers	Workers departing in peak hour
1	2	€40,000	1	1
2	3	€50,000	2	1
3	4	€55,000	1	2
4	4	€40,000	3	1

There are 100 of type 1, 200 of type 2, 350 of type 3 and 50 of type 4. Assuming for the purposes of the example that shopping, social and work vehicle-based trips all peak at the same time, determine the total no. of peak hour trips using the generation models described in examples 1 and 2.

Solution:

Vehicle based shopping trips

Type 1: 0.12 + 0.09(2) + 0.011(40) – 0.15(2.05) = 0.43 trips/HH x 100HH = 43.25 trips

Type 2: 0.12 + 0.09(3) + 0.011(50) – 0.15(2.05) = 0.632 trips/HH x 200HH = 126.5 trips

Type 3: 0.12 + 0.09(3) + 0.011(55) – 0.15(2.05) = 0.687 trips/HH x 350HH = 240.6 trips

Type 4: 0.12+0.09(4) +0.011(40) – 0.15(2.05) = 0.612 trips/HH x 50HH = 30.62 trips

Therefore there will be a total of 441 vehicle based shopping trips

Vehicle-based social trips

Type 1: 0.04+0.018(2) + 0.009(40) + 0.16(1) = 0.596 trips/HH x 100HH = 59.6 trips

Type 2: 0.04+0.018(3) + 0.009(50) + 0.16(2) = 0.864 trips/HH x 200HH = 172.8 trips

Type 3: 0.04 + 0.018(3) + 0.009(55) + 0.16(1) = 0.749 trips/HH x 350HH = 262.15 trips

Type 4: 0.04 + 0.018(4) + 0.009(40) + 0.16(3) = 0.952 trips/HH x 50HH = 47.6 trips

Therefore there will be a total of 542.15 vehicle-based social trips

Vehicle based work trips:

Type 1: (1 x 100) = 100
Type 2: (1 x 200) = 200
Type 3: (2 x 350) = 700
Type 4: (1 x 50) = 50

Total work trips

Total of all trips = 2033

Question 2

Describe mode choice as part of the four stage model, with reference to the main factors which influence mode choice. [6]

Question 2

(a)

The choice of transport mode is probably one of the most important steps in the four-stage model. Almost without exception public transport modes make the most use of road space more efficiently than the private car. The issue of mode choice, therefore, is probably the single most important element in transport planning and policymaking. It affects the general efficiency with which travel occurs in urban areas. Given the importance of mode choice it is important that mode choice models incorporate as many factors as possible which impact upon mode choice. The purpose of the mode choice stage in the four-stage model is to identify which trips are likely to be taken by the different modes of transport available.

The factors which influence mode choice can be classified into three groups:

1. Characteristics of the trip maker:
- Car availability/ownership
- Possession of a driving licence
- Household structure
- Income
- Residential density

2. Characteristics of the journey:
- The trip purpose
- Time of day

3. Characteristics of the transport facility
- Relative travel time
- Monetary costs/fare
- Availability of parking

b. Table 1 presents the data collected in a household (HH) survey.

Table 1

Type	Household size	Annual Income €,000	No. of non-workers	No. workers departing in the peak hour
1	3	25	2	1
2	4	50	2	2
3	5	60	3	2
4	3	70	2	1

The total number of household types is given in Table 2.

Table 2

Household type	No. of households
1	100
2	250
3	300
4	75

The following linear regression model estimates the number of social/recreation trips.

$$y_1 = 0.08 + 0.01x_1 + 0.009x_2 + 0.02x_3$$

Where:
y_1 = coefficient for the number of household peak hour social/recreation trips
x_1 = Household annual income
x_2 = Household size
x_3 = Number of non-working household members

The following linear regression model estimates the number of retail trips.

$$y_2 = 0.5 + 0.01x_1 + 0.004x_2 + 0.01x_3$$

Where:
y_2 = coefficient for the number of household peak hour retail trips
x_1 = Household annual income
x_2 = Household size
x_3 = Number of non-working household members

Using the data above calculate the total number of peak hour work-based trips, retail and social/recreation trips.

[8]

Number of social/recreation trips
Type 1: 0.08 + 0.01(25) + 0.009(3) + 0.02(2) = 0.397 trips/HH x 100 HH = 40 trips
Type 2: 0.08 + 0.01(50) + 0.009(4) + 0.02(2) = 0.656 trips/HH x 250 HH = 164 trips
Type 3: 0.08 + 0.01(60) + 0.009(5) + 0.02(3 = 0.785 trips/HH x 300 HH = 236 trips
Type 4: 0.08 + 0.01(70) + 0.009(3) + 0.02(2) = 0.847 trips/HH x 75 HH = 64 trips

Therefore there will be a total of 504 vehicle based peak hour social/ recreation trips

Number of retail trips
Type 1: 0.05 + 0.01(25) + 0.004(3) + 0.01(2) = 0.332 trips/HH x 100 HH = 33 trips
Type 2: 0.05 + 0.01(50) + 0.004(4) + 0.01(2) = 0.586 trips/HH x 250 HH = 147 trips
Type 3: 0.05 + 0.01(60) + 0.004(5) + 0.01(3) = 0.7 trips/HH x 300 HH = 210 trips
Type 4: 0.05 + 0.01(70) + 0.004(3) + 0.01(2) = 0.782 trips/HH x 75 HH = 58 trips

Therefore there will be a total of 448 vehicle based peak hour social/ recreation trips

Work based trips
Type 1: 1 * 100 = 100
Type 2: 2 * 250 = 500
Type 3: 2 * 300 = 600
Type 4: 1 * 75 = 75

Therefore there will be a total of 1275 vehicle based peak hour trips.

c. Describe the concept of generalised cost, with reference to the differences between the generalised cost of using public transport and private transport.

[6]

(c)

Generalised cost in relation to transport modelling refers to the cost of using a specific mode of transport. Generalised cost is an aggregated cost which represents several aspects of a specific mode of transport. This cost does not just refer to the financial cost (fare or fuel) but the overall cost in terms of travel time etc. In terms of the generalised cost of public transport, it can include aspects of travel time, wait time, comfort, and modal preference. The more aspects of the public transport service which are included in the generalised cost, the closer the estimate is to the real preferences of the user. The generalised cost of private transport tends to take fewer attributes of the trip and focuses mainly upon costs such as fuel costs and non-fuel costs such as parking.