DAVID SIMMONDS CONSULTANCY
URBAN, REGIONAL AND TRANSPORT PLANNING

LATIS Lot 3

TELMoS12
Model Development Report

Report prepared for Transport Scotland

Prepared by

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SUMMARY

This report provides a technical description of TELMoS12. It covers:

- the main inputs of the model: the base year database, the scenarios and the planning policy inputs
- the calibration of the DELTA sub-models used within the TELMoS12 land use model
- the interface between the land use and transport models

Introduction

In chapters 1 and 2 we describe the structure of the report and provide an overview of the TELMoS12 model, describing the key processes modelled.

Definitions

Chapters 3 and 4 deal with definitions and with the correspondence between definitions, data and the database files themselves.

The databases and the preparation of data

Chapters 5, 6 and 8 describe the sources of data used when preparing the base year data base. These include the initial results from the 2011 Census (for demographic and households), commercial floorspace and residential statistics, the Generalised Costs that are computed by the transport model and a range of Area Level data.

Where appropriate, the chapters describe the processing of 2011 data and the steps taken to develop a new 2012 base-year dataset.

Scenario inputs

Chapter 9 describes the economic and demographic scenario which is implemented in TELMoS12 and the processes involved in calibrating the land use model to these scenarios.

Planning policy inputs

Chapter 10 identifies the planning policy inputs used in the application of the model to date.

Calibration of the DELTA sub-models

Chapter 101 gives an overview of the different sub-models used within TELMoS12 together with an introduction to the calibration process. Chapters 12 to 212 then document the models in more detail. These include the processes of development (the construction and demolition of commercial and residential floorspace), household transition and the changing household structure across the modelled area, car ownership (and how the numbers of cars changes over time and in response to the changing household structure within each zone), household and employment location, migration, changes in the residential quality and changes in employment status.

The Interface with the Transport Model

Chapter 23 documents the interface between TELMoS12 and TMfS12. It describes the information that is passed from the land use model to the transport model.

[end of summary]

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ABBREVIATIONS

Abbreviation	Meaning
BRES	Business Register Employment Survey
CSTCS	Central Scotland Transport Corridors Study
DELTA	Land-use/economic modelling package developed by DSC
DfT	Department for Transport
DSC	David Simmonds Consultancy Limited
GIS	geographic information system
HGV	heavy goods vehicle
JATES	Joint Authorities' Transport and Environment Study (Lothian)
LGV	light goods vehicle
LUTI	land-use/transport interaction
NATCOP	National Car Ownership Program (model)
NTEM	National Trip-End Model (and the household, population, employment, income and car-ownership projections used in NTEM and distributed by TEMPRO)
OGV	other goods vehicle
Pcu	passenger car units
REM	Regional Economic Model
RICS	Royal Institution of Chartered Surveyors
SAR	Sample of Anonymised Records (from 1991 and 2001 Censuses of Population)
SEL	socio-economic level (in FLUTE and other DELTA models)
SimDELTA	version of DELTA using microsimulation to model households and persons
TEMPRO	Trip End Model PROgram (software commissioned by DfT to distribute NTEM inputs and outputs)
TMfS	Transport Model for Scotland
VOA	Valuation Office Agency
WebTAG	Web-based Transport Appraisal Guidance (DfT)

Note: names such as AC12, ML12 etc are program names and not abbreviations; the DELTA programs used in TELMoS are listed in Table 2-1.

GLOSSARY

This table provides a summary explanation of various terms which have a specific meaning in the DELTA package and hence in TELMoS.

Term	Meaning	For more detail see:
Activity	One of the categories of households or employment represented in TELMoS	Chapter 3
Area	The higher-level units of space in TELMoS	For area map see Figure 2-3
Area Model	The Area Model calculates the new floorspace which is developed in each Area as a result of local demand	See Chapter 13
Buffer Area	The parts of the *Modelled Area* outside the *Fully Modelled Area*, represented in less detail, and with not all processes modelled	For area map see Figure 2-3. For processes modelled in less detail or not at all see Table 2-1
Buffer Zone	A *Zone* within the *Buffer Area*	See Chapter 2
External Zones	A *Zone* outside the *Modelled Area*, represented only in certain sub-models for particular processes eg as a source of workers commuting into the *Modelled Area* (or the destination of those commuting out)	See Chapter 2
Fully Modelled Area	The part of the *Modelled Area* represented in more detail and with all the model processes working in full. Note that this is intended to be larger than the "study area" or "policy area" within which policy interventions may be tested	For area map see Figure 2-3
Fully Modelled Zone	A *Zone* within the *Fully Modelled Area*	See Chapter 2
Modelled Area	The total area represented by the model, ie the *Fully Modelled Area* plus the *Buffer Area*. (Note that this excludes external zones.)	For area map see Figure 2-3
Regional Model	The Regional Model calculates the new floorspace which is developed as a result of demand across the Fully Modelled Area	See Chapter 13
Socio-Economic Level (SEL)	One of the occupation-based categories into which households and workers are grouped	See Chapter 3
Zone	The finest geographic unit represented within FLUTE: may be *Fully Modelled*, *Buffer* or *External*	See Chapter 2

1 INTRODUCTION

1.1 Background

1.1.1 David Simmonds Consultancy (DSC) has been commissioned to update TELMoS and to prepare a Part 1 Upgrade. This was to include the following tasks:

i. model definition and database: new “base year” of 2012
ii. incorporation of APPI data in 2012 base and forecast years
iii. Regional Economic Model:
    a. Updated economic data sources (creation of a new economic scenario)
    b. New airport scenarios
    c. New island scenarios
iv. Household transition model: recalibration of the demographic scenario
v. Car ownership: refresh car ownership model coefficients
vi. Household and Employment Location Models: recalibrate the household location model
vii. accessibility: recalibration of the model, by reference to new TMfS:12 base year costs and external sources
viii. documentation

1.1.2 This report represents the documentation associated with this work.

1.2 Structure of the report

1.2.1 This report is effectively in three parts.

1.2.2 The first part consists of chapters 2 to 4 which give overview of the model and the definitions of activities and land use used within TELMoS.

1.2.3 Chapters 5 to 9 then describe the inputs to the model, first in terms of the base year database and the methods used to create it, then by discussing the demographic and economic scenarios implemented within this version of TELMoS, and finally by describing the planning policy inputs to the model. The scenarios and planning policy inputs can be changed in future versions of TELMoS.

1.2.4 The third part then describes the various components of TELMoS and the calibration of their coefficients. Chapter 10 describes the model as a whole (including some necessary description of the DELTA package), and the DELTA components used in TELMoS and provides an overview of how they have been calibrated. Chapters 12 to 23 go in detail through each of the components. Appendix A supplies the mathematical specification of the model.

2 OVERALL STRUCTURE OF TELMOS

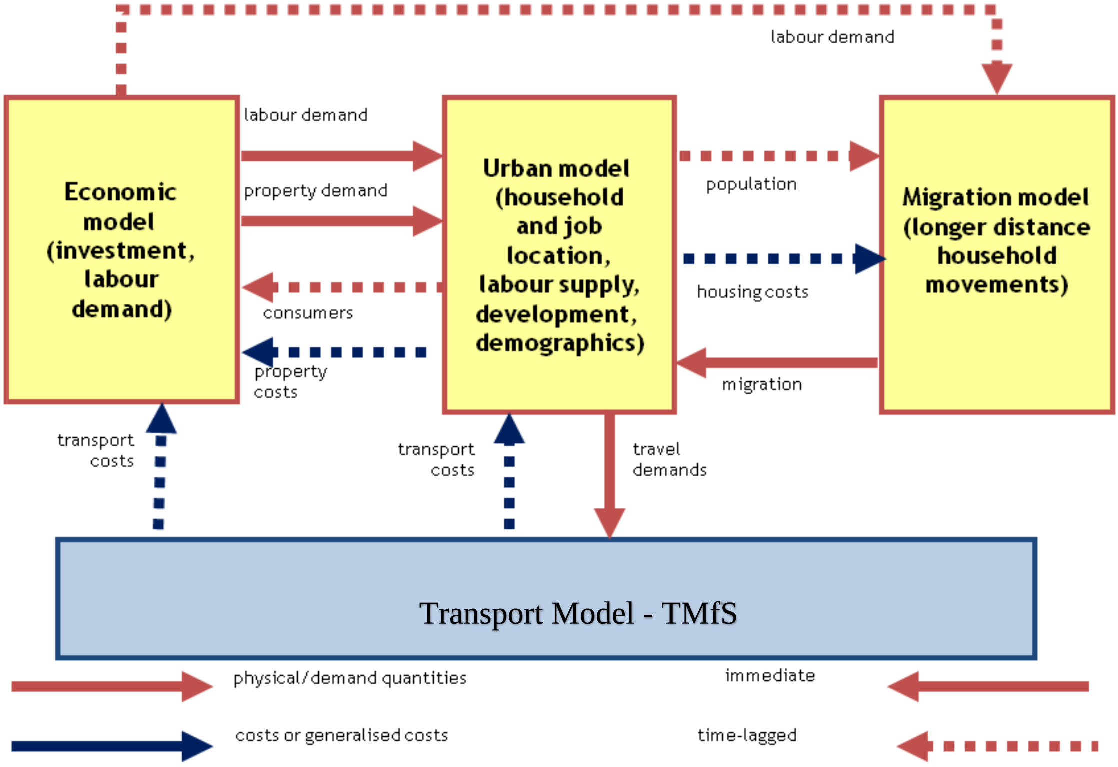
2.1 <u>General overview of the TELMoS application</u>

2.1.1 The main components of the model are illustrated in Figure 2-1.

2.1.2 Considering these components, the transport and urban models work at the level of zones, whilst the migration and economic models work at the broader level of areas. Areas typically correspond to travel-to-work areas within Scotland, zones represent finer units within these areas.

2.1.3 The **transport model** takes inputs which describe activities (different categories of residents and jobs) by zone, for a given year. From this and from input transport system data it forecasts travel by car and by public transport. In doing so, it estimates costs and times of travel between each pair of zones, allowing for congestion caused by the forecast traffic.

Figure 2-1 Main Components of TELMoS



2.1.4 The **economic model** forecasts the growth (or decline) of the sectors of the economy in each of the areas modelled. Its inputs include forecasts of overall growth in output and productivity. The forecasts by sector and area are influenced by:

- costs of transport (from the transport model)
- consumer demand for goods and services (from the urban model)
- commercial rents (from the urban model)

2.1.5 Forecast changes in employment by sector and area are passed to the 'urban' model.

2.1.6 The **urban model** forecasts the zonal location of households and jobs within the areas that are modelled in detail. Locations are strongly influenced by the supply of built floorspace, and hence the urban model is a set of property models as well as a set of inter-related location models. Locations are also influenced by accessibility, with different measures of accessibility influencing different activities, and by environmental variables. Households are influenced by accessibility to workplaces and services. Businesses are influenced by accessibility to potential workers and customers.

2.1.7 The locations of households and jobs are fed back to the transport model to generate travel demands. Household numbers are also used to calculate consumer demand for goods and services in each area, for use in the economic model. The rents arising from competition for property in each area affect both the economic and migration models. Information on job opportunities is passed to the migration model.

2.1.8 The **migration model** forecasts migration **between** areas within the modelled area. Movements **within** areas are forecast in the urban model. The inputs to this model include job opportunities and housing costs, from the urban model. Job opportunities are a strong incentive to migration; housing costs are a generally weak disincentive.

2.1.9 TELMoS is essentially a model of land-use and economic **changes** over time, working in one year steps. At intervals, usually every fifth year, land-use data is passed to the transport model, TMfS. The transport model is run and matrices of generalised costs are passed back to TELMoS. Part of the sequence is shown in Figure 2-2.

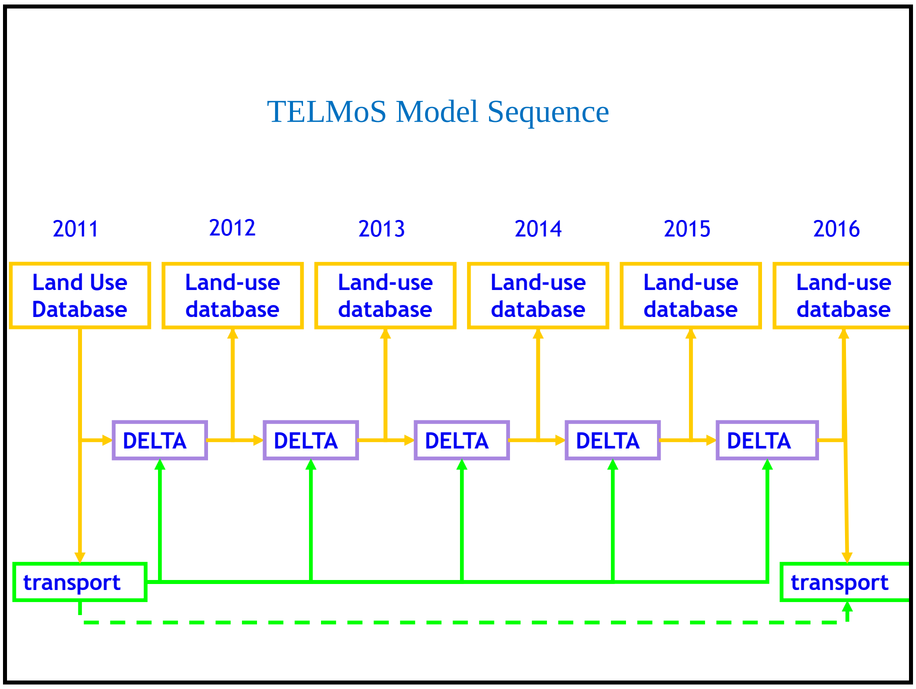


Figure 2-2 TELMoS land use and transport model sequence (five-year example)

2.1.10 TELMoS gradually responds to the changed generalised costs over the following years. Some responses are quick, others very slow. There are numerous time lags in the model, so indirect responses can take many years to work through the system. Some of the components of the land use model are iterated to a very partial equilibrium in each year, but the system as a whole is always forecasting change over time and never reaches a final "equilibrium state".

2.1.11 In line with other applications of the DELTA software there is a differentiation between the Fully Modelled Area and the external zones. The Fully Modelled Area is the main focus of interest, covering the whole of Scotland (see Figure 2-3). The external zones cover other parts of mainland Britain.

2.1.12 The model represents processes at two spatial levels: the local or zone level and the strategic or Area level. Within the Fully Modelled Area there are 712 zones grouped into 47 Areas. In all cases zones nest within areas. There are 8 external zones.

2.2 Sequence of Model Components

2.2.1 TELMoS is a conventional aggregate model, working on vectors of numbers representing the levels of employment and population by zone, rather than on samples of individual households or firms.

2.2.2 The sequence of processes within the model for each year goes from the changes in households, employment and floorspace to the interactions between these. The logic behind this is that the separate processes (particularly for household changes, which reflect independent demographic processes such as ageing) provide the context for the more complex processes such as the interactions between floorspace and the activities which use floorspace, or between labour supply and demand. The sequence of the components within one year is fixed and is shown by the green column in Table 2-1.

2.2.3 In addition the accessibility measures are updated each year, describing accessibilities at a particular point in time. This is done after all the land-use changes for the year have been completed. In years when the transport model is run, it is run after the land-use changes and before the accessibility calculations.

2.3 Programs, input files, block names and test codes

2.3.1 The names of the DELTA programs which implement the various components are shown in the left-hand columns of Table 2-1. The main components implement the main forecasting calculations; the other components do data processing to prepare information for the main components (eg assembling data from numerous files into a single set of input), or as post-processing (eg to merge data just output from one process with other data).

2.3.2 Almost every program has an input file of coefficients, with a name in the form <model-component><year-code><test-code>.INP. For example, the input to the development model, MD12, in year 2014 of test BQ will be MD1214BQ.INP. When referring to a set of files rather than to a specific file, this is usually abbreviated to the form MD12<><>.INP. A different two-character test code is used for each forecast. These codes become important in applications to identify precisely which run of the model is referred to in eventual reporting of results

2.3.3 Input files are in some cases read by more than one program, to ensure that each item of information is entered once into an input file: for example, the coefficients for income calculations are entered in the location model file ML12<><>.INP, but are also read by the income model MI12.

2.3.4 Each file is divided into blocks of data, identified by six-character identifiers such as ACIN01; these identifiers are in effect arbitrary.

2.3.5 Readers of this document do not strictly need to know the program names, but in practice they are often used in discussion and are helpful in referring unambiguously to specific parts of the model. File and block names are still less relevant to the reader remote from the operation of the model, but are included because this note is intended to form part of the eventual documentation for “hands-on” model users, as agreed at the beginning of the project.

2.3.6 Note that there is no specific component for interface to TMfS the transport model works directly from the DELTA output files.

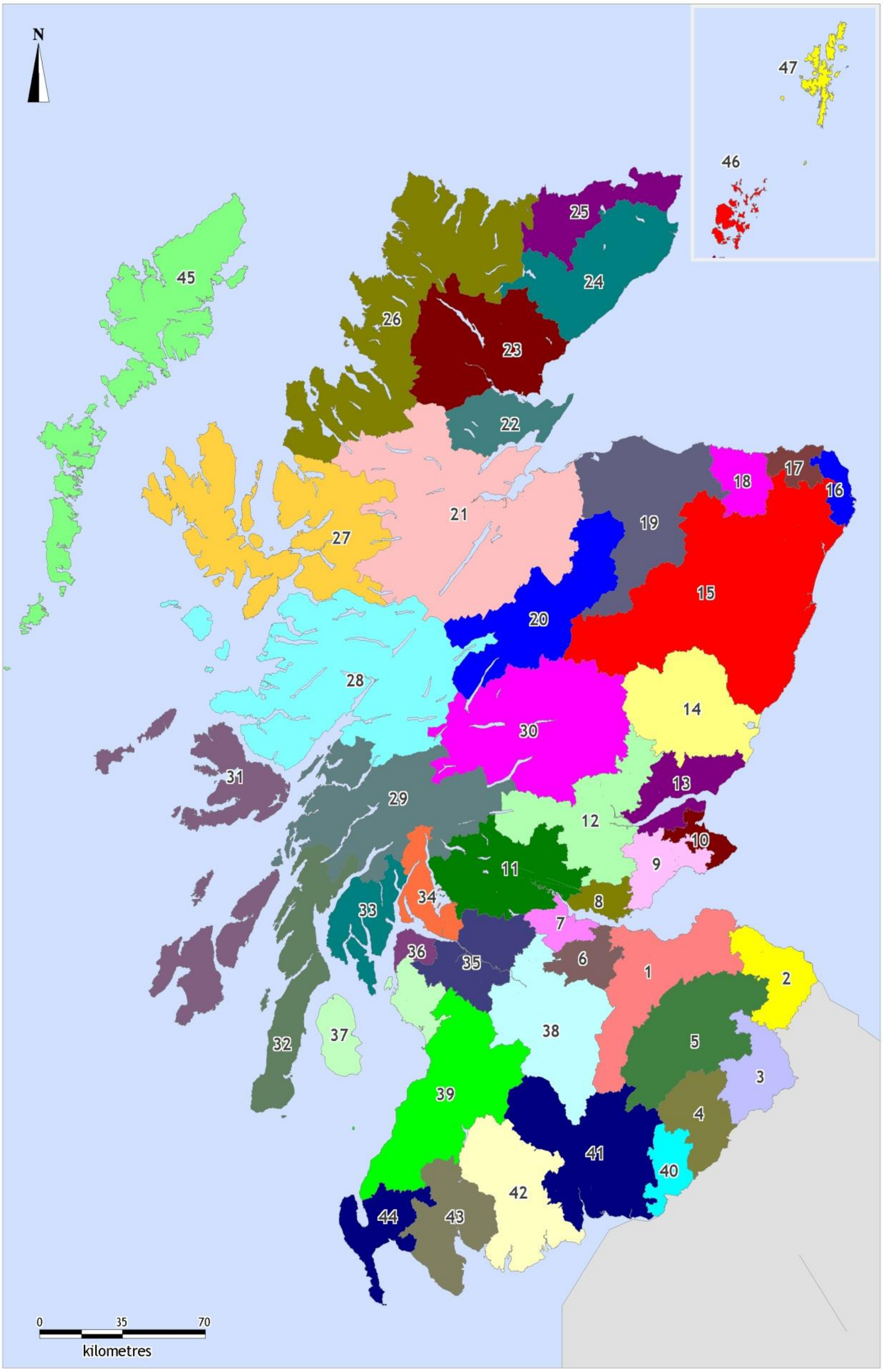


Figure 2-3 TELMoS Fully Modelled Area

Table 2-1 TELMoS components, program names, extent

<table>
<tr><th colspan="2">Programs</th><th rowspan="2">Component and function(s)</th></tr>
<tr><th>Main</th><th>Other</th></tr>
<tr><td>MD12</td><td></td><td rowspan="2">Development model</td></tr>
<tr><td></td><td>PD12</td></tr>
<tr><td></td><td>PX12</td><td rowspan="2">Employment growth model</td></tr>
<tr><td>MK12</td><td></td></tr>
<tr><td>MP12</td><td></td><td>Production and trade model</td></tr>
<tr><td>MT12</td><td></td><td>Household transition model</td></tr>
<tr><td>MM12</td><td></td><td>Household migration model</td></tr>
<tr><td>MI12</td><td></td><td>Household income model</td></tr>
<tr><td>MC12</td><td></td><td>Car-ownership model</td></tr>
<tr><td></td><td>PL12</td><td rowspan="4">Location models:
Household and housing market
Employment and commercial/other floorspace</td></tr>
<tr><td></td><td>PS12</td></tr>
<tr><td>ML12</td><td></td></tr>
<tr><td></td><td>PZ12</td></tr>
<tr><td>ME12</td><td></td><td>Employment status model</td></tr>
<tr><td>MQ13</td><td></td><td>Housing quality model</td></tr>
<tr><td></td><td>PC12</td><td>(assembles cost data for next year)</td></tr>
<tr><td></td><td>IV12</td><td>(assembles data for accessibility calculations below)</td></tr>
<tr><td colspan="3">in a transport model year, the transport model runs here</td></tr>
<tr><td>AC12</td><td></td><td>Accessibility calculations</td></tr>
<tr><td>IT12</td><td></td><td>convert generalized costs by purpose to generalized costs by employment activity (for use in AA12)</td></tr>
<tr><td>AA12</td><td></td><td>area accessibility calculations</td></tr>
<tr><td>IA12</td><td></td><td>convert accessibilities by purpose to accessibilities by activity, and environmental measure from SYSTM+ output to DELTA variable</td></tr>
<tr><td></td><td>IB12</td><td>(post-process employment status data)</td></tr>
</table>

3 MODEL DEFINITION

3.1 Model definition file

3.1.1 The DELTA model definition file, DELTAMOD.DEF, defines the overall dimensions of the model and is used to specify the different elements to be operated in a particular model application. All the DELTA programs read this file.

3.1.2 The following sections document the parts of the model definition file.

3.1.3 Additional sections at the end of this chapter refer to the other definition files and to definitions included in other inputs.

3.2 DELTA and transport model years

3.2.1 The DELTA model is operated in one-year steps. The model definition file:

- lists all years during the forecast period (ie to 2037) and the eleven years prior to the base year (ie from 2001)
- defines 2012 as DELTA base year (year 0) for model running
- defines the two-character alphanumeric codes used as abbreviations for the year

3.2.2 DELTA needs to know in which years the transport model is run. This information is input via the **test** definition file. When required, DELTA-only tests can be carried out by deleting some transport model years from this test definition. Standard TELMoS runs start at the point immediately following the 2012 transport model run, ie with the 2012 accessibility calculations. The transport model years are 2017, 2022, 2027, 2032 and 2037.

3.3 Zones, areas and other model dimensions

3.3.1 Table 3-1 lists some of the key model dimensions. These include the numbers of zones, the person types, socio-economic levels, car ownership categories and trip purposes. These are contained within the model definition file in blocks DF1101 and DF1201.

3.3.2 Block DF1102 defines a number of additional model options. These are listed within Table 3-2.

Table 3-1 Model dimensions entered as values

Dimension	Value
Fully Modelled Area Zones	712
Buffer Area Zones	0
External Zones	8
Household socio-economic levels	2
Worker socio-economic levels	2
Person types	4
Car-ownership levels in household data	3
Car-ownership levels in matrix data	3

Dimension	Value
Modes in accessibility inputs	5
Purposes in accessibility inputs	6
Model Version	1240
Number of socio-economic groups in transport model	1
Number of car-ownership levels in transport model	3

Table 3-2 Model definitions (Block DF1102)

Key	**Description**	Option
ACDF	Controls where blocks ACDFA1 and ACDFA2 are found	1
ADVM	Use of the Area Development Model in MD12	1
ALAG	Time Lag in calculating floorspace per worker	1
ARAC	Choice of Accessibility Function in AA12	1
ASRV	Defines use of accessibility and environmental inputs in producing ASRV file	1
CNCD	Constraints applied on calculation of consumer demand	1
ENVR	Defines use made of ENVR files	2
IACM	Defines treatment of car ownership levels and modes in IA12 accessibility calculations	1
INVW	Fixed or calculated household incomes	1
ITBH	Sets number of header lines in model output files (ITABs)	5
MCVR	Controls calculation of car-ownership proportions	1
MDQL	Controls application of quality input for new floorspace	1
MEEA	Defines adjustment to zonal employment	1
MENW	Defines use of scaling procedure for non-working residents	1
MESH	Applies minimum proportion of households by employment level where absolute values are small	1
MPED	Distributes export production in proportion to capacity	1
NMEM	Demand for floorspace is driven by changes in the regional economic model’s calculated employment	1
OLGA	Defines ML12 convergence algorithm that is used	5
RSDU	Use of additional file of residual disutilities in regional economic model	1
SPCS	Defines how treatment of space costs are treated in the regional economic modle	2
TMDL	Defines interface with transport model	2
XOMB	Defines how mobile floorspace is treated in calculating expected occupier	2

XONF	Defines that all new floorspace is expected to be occupied (and no proportion is left intentionally vacant)	1
XOVF	Defines how vacant floorspace is treated within the expected occupier calculation	2
XPRO	Defines relocation constraints	0

3.3.3 The zone system remain the same as for TELMoS07. The two categories of zones are numbered as follows:

- **Fully Modelled Area**, zones 1 to 712
- **External Zones** zones 713 to 720

3.3.4 We note that within the Transport Model, TMfS12, additional zones have been introduced along the corridor of the A9. These are not represented in this version of TELMoS12. The aggregation of the finer level zone generalised costs and disaggregation of planning data from TELMoS zones to the finer-level are currently carried out within the Transport Model.

3.3.5 The Area level of the model works on internal and external areas. The area system is used solely within the migration and economic components of the land-use model and is invisible to the transport model (and, for many purposes, invisible to the user of model results).

3.3.6 The area definitions remain the same as for TELMoS07. They are shown in Table 3-3.

Table 3-3 Correspondence of zones to areas

Area Code	Area Description	Zones
1	Edinburgh	22, 36-48,50-118,709
2	Berwick (pt)	33-35,49
3	Kelso and Jedburgh	31-32
4	Hawick	27
5	Galashiels and Peebles	23-26, 28-30
6	Livingston & Bathgate	119-128, 130-142, 369
7	Falkirk	129, 371-391
8	Dunfermline	477-496
9	Kirkcaldy & Glenrothes	497-513, 515-516, 518-519,522
10	St Andrews & Cupar	517, 521,524-525
11	Stirling & Alloa	459, 461-476, 528,
12	Perth & Blairgowrie	527, 530, 532-533, 535-544,
13	Dundee	514, 520, 523, 545-565, 568-570, 572-574, 577,
14	Forfar & Montrose	566-567, 571, 575-576, 578,
15	Aberdeen	579-582, 584, 586, 588-590, 592-599, 601-604, 606, 609-634,712
16	Peterhead	607-608
17	Fraserburgh	600, 605

Area Code	Area Description	Zones
18	Banff	583, 585, 587, 591
19	Moray	635-646
20	Badenoch	682, 700,702
21	Inverness & Dingwall	673-674,676, 678-679, 681, 683-687, 691, 693-694, 698
22	Invergordon	680, 688-689, 697,
23	Dornoch & Lairg	677, 690, 692, 695-696
24	Wick	701,704,706
25	Thurso	699,703, 705
26	Ullapool & Gairloch	670, 675,
27	Skye & Localsh	665, 669,
28	Fort William	666-668, 671-672
29	Oban	458, 652-653, 656,
30	Pitlochry	526,529, 531, 534,
31	Mull & Islay	647-649
32	Lochgilphead & Campbeltown	650-651
33	Dunoon & Bute	654-655,
34	Dumbarton	444-450, 657-662
35	Glasgow	143,145,147,149-150,152,155-156, 158, 232-325, 328, 333, 336, 338, 342, 346, 350,352, 354, 359, 392-428, 451-457, 460 ,711
36	Greenock	219, 429-443
37	Irvine & Arran	203, 214-218, 220-231,
38	Lanarkshire	144,146,148,151, 153-154,157, 159-182, 326-327,329-332, 334-335, 337, 339-341, 343-345, 347-349, 351, 353, 355-358, 360-368, 370,
39	Ayr & Kilmarnock	183- 202, 204-213, 710
40	Carlisle (pt)	20-21
41	Dumfries & Annan	7-8,10-19
42	Kirkcudbright	4-6,9
43	Newton Stewart & Wigtown	2-3
44	Stranraer	1
45	Eilean Siar	663-664
46	Orkney Islands	707
47	Shetland Islands	708

3.4 Activity definitions

3.4.1 The term ‘activity’ is used throughout DELTA to refer to the various detailed categories of households and of employment. There are a total of 43 activities;

activities 1 to 20 inclusive are household types and activities 31 to 55 refer to economic activity.

3.4.2 The household activities are shown in Table 3-4 and are based upon a mixture of age, composition and employment status, further disaggregated by socio-economic level. These definitions in turn rely upon the person types defined in Table 3-5 and the socio-economic levels described in Table 3-7.

Table 3-4 Household activity types

Activity	Description
1	Single adult younger (16-44), manual
2	Single adult younger (16-44), non-manual
3	Single adult non-retired older (45-74), manual
4	Single adult non-retired older (45-74), non-manual
5	Single adult retired, manual
6	Single adult retired, non-manual
7	Single adult parent (16-74, with children), manual
8	Single adult parent (16-74, with children), non-manual
9	2 adults household younger (both 16-44), at least one non-retired, no children, manual
10	2 adults household younger (both 16-44), at least one non-retired, no children, non-manual
11	2 adults household older (one or both 45+), at least one non-retired, no children, manual
12	2 adults household older (one or both 45+), at least one non-retired, no children, non-manual
13	2 adults household with children, manual
14	2 adults household with children, non-manual
15	Couple, both retired, manual
16	Couple, both retired, non-manual
17	3+ adults no children, manual
18	3+ adults no children, non-manual
19	3+ adults with children, manual
20	3+ adults with children, non-manual

3.4.3 The person types are defined as shown in Table 3-5.

Table 3-5 Person types

Type	Description
Children	Any person under 16 years of age
Non-workers	Any person between the ages of 16 and 74 inclusive, who is not in employment and who is not retired
Workers	Any person between the ages of 16 and 74 inclusive who is in paid employment
Retired	Any person aged 75 or over and any person between the ages of 16 and 74 inclusive who is classified as 'economically inactive retired'

3.4.4 Table 3-6 shows the employment activity classification. Many activities are split into separate activities by socio-economic level, on the basis that different types of workers occupy different types of floors. Socio-economic Level 1 is treated as non-manual whilst Level 2 is treated as manual for this purpose. The socio-economic levels are defined in Table 3-7 and the floorspace types in Table 3-8.

Table 3-6 Employment activity definitions

Activity	Description (with SIC code to which the activity belongs)		Floorspace occupied
31	A - Agriculture, hunting and forestry	Non-manual	office
32	A - Agriculture, hunting and forestry	Manual	-
33	B – Fishing	Non-manual	office
34	B – Fishing	Manual	-
35	C – Mining and quarrying	Non-manual	office
36	C – Mining and quarrying	Manual	-
37	D – Manufacturing	Non-manual	office
38	D – Manufacturing	Manual	industrial
39	E - Electricity, gas and water supply	Non-manual	office
40	E - Electricity, gas and water supply	Manual	industrial
41	F – Construction	Non-manual	office
42	F – Construction	Manual	industrial
43	G – Wholesale and retail trade, repairs (retail)	Manual and Non-manual	retail
45	G – Wholesale and retail trade, repairs (other)	Non-manual	office
46	G – Wholesale and retail trade, repairs (other)	Manual	industrial
47	H – Hotels and restaurants	Manual and Non-manual	leisure/hotel
48	I – Transport, storage and communications	Non-manual	office
49	I – Transport, storage and communications	Manual	industrial
50	J – Financial intermediaries (financial management)	Manual and Non-manual	office
51	J – Financial intermediaries (local financial services)	Manual and Non-manual	office
52	K – Real estate, renting and business activities	Manual and Non-manual	office
53	L – Public administration & defence, social security	Non-manual	office

Activity	Description (with SIC code to which the activity belongs)		Floorspace occupied
54	L – Public administration & defence, social security	Manual	industrial
55	M – Education	Manual and Non-manual	education
56	N – Health and social work	Manual and Non-manual	health
57	O, P, Q – Other	Non-manual	office
58	O, P, Q – Other	Manual	industrial

3.4.5 The DELTA definition file only establishes the existence of a particular activity; it does not specify the composition of that activity. The definition of the numbers of persons of each type in each household activity, ie the information which actually tells the software that a household of activity 1 contains a single non-manual adult, is input within the employment status model (see Chapter 20).

Table 3-7 Definition of DELTA socio-economic levels

DELTA SEL	Title	Contains 2001 Census of Population SEGs:	
1	Non-manual workers	AB	Higher and intermediate managerial/administrative/professional
		C1	Supervisory, clerical, junior managerial/administrative/professional
2	Manual workers	C2	Skilled manual workers
		D	Semi-skilled and unskilled manual workers
		E	On state benefit, unemployed, lowest grade workers

3.4.6 The information on number of households and on numbers of persons by type is recorded in the activity database file. This is described in Chapter 4.

3.4.7 The process of changing employment status within the model is carried out in the employment status sub-model. This is described in Chapter 20.

3.5 Activity group definitions

3.5.1 The DELTA software uses “activity groups” to specify (a) categories of activities which have to be distinguished, e.g. to identify which activities are households and which are employment; and (b) to provide an abbreviated way for the user to refer to multiple activities in setting up input files. The definitions are critical to the interpretation of other model inputs and should not be changed, but they are not significant in this Report.

3.6 Floorspace

3.6.1 The model works with seven categories of floorspace, all measured in square metres. These are shown in Table 3-8.

Table 3-8 TELMOS land use model floorspace category and development process definitions

DELTA floorspace category	Represents	Greenfield develop-ment process	Brownfield develop-ment process	Edinburgh and Glasgow high density residential develop-ment	Residential develop-ment outwith Edinburgh and Glasgow
1	Residential			1	8
2	Retail	2	9		
3	Office	3	10		
4	Industrial	4	11		
5	Leisure/ Hotel	5	12		
6	Education	6	13		
7	Health	7	14		

3.6.2 The DELTA model does not represent land directly. The software is designed to expect a category of land corresponding to each category of floorspace, but in the present implementation any data about "land" is a measure of floorspace.

3.7 Development model definitions

3.7.1 TELMoS is configured to represent twenty development processes. For residential land use two development processes are defined; development process one represents high density development within the City of Edinburgh and Glasgow City. An expected occupier function is applied to this development process whereby new floorspace is occupied by single adult or two adult households. Development process 8 is applied to residential development elsewhere in Scotland. Development processes 2 to 14 represent greenfield and brownfield development of each of the other six floorspace types, as specified in Table 3-8.

3.8 Definition of car-ownership and car-availability levels

3.8.1 Car ownership is modelled for all 20 household activities. The model works with three levels of car-ownership, as shown in Table 3-9. Beware of the possible confusion between the numbering of the levels (1, 2...) and their meaning (no car, 1 car...).

Table 3-9 Car ownership levels

DELTA car ownership level	Represents households with….
1	no car
2	one car
3	two or more cars

3.9 Migration model definition

3.9.1 This definition specifies which activity groups are to be considered as possible migrants. The present implementation allows all non-retired households to migrate. In practice, this requires the specification of an appropriate activity group, defined as ‘all non-retired household activities’, in the migration model definition block.

3.10 Regional Economic Model Definition

3.10.1 Two blocks of input are required to create the basic definition of the regional economic model (REM).

3.10.2 The first block specifies

- which of the defined activities are to be treated as sectors in the REM
- which of the defined activities are to be treated as the urban model employment activities corresponding to these sectors

3.10.3 Table 3-10 specifies the matching between urban model activities (measured as employment by zone) and regional economic sectors (measured primarily by output and value-added by area).

Table 3-10 Match of urban model activities to REM sectors

Urban Activities		REM Sectors	
31	Agriculture, hunting and forestry	101	Agriculture, forestry and fishing
32			
33	Fishing		
34			
35	Mining and quarrying	102	Mining
36			
37	Manufacturing	103	Manufacturing
38			
39	Electricity, gas and water supply	104	Energy and water
40			
41	Construction	105	Construction
42			
43	Wholesale & retail trade, repairs - retail	106	Distribution and catering
45	Wholesale & retail trade, repairs - other		
46			
47	Hotels & restaurants		
48	Transport, storage & communications	107	Transport and communication
49			
50	Intermediaries – financial management	108	Finance and business

Urban Activities		REM Sectors	
51	Intermediaries – local financial services		
52	Real estate, renting & business activities		
53	Public administration, defence, social security	109	Public administration
54			
55	Education		
56	Health		
57	Other	110	Other services
58			

3.10.4 The additional sectors used to represent different categories of imports to Scotland are as shown in Table 3-11.

Table 3-11 Definition of import sectors

Sector	represents
111	Goods from Rest of UK
112	Goods from Rest of World through England
113	Goods from Rest of the World, not through England
114	Services from Rest of UK
115	Services from Rest of World through England
116	Services from Rest of the World, not through England

3.10.5 Note that these sectors are defined as special sectors representing different categories of imports by the area capacities database. This is set up so that each of these sectors has a non-zero capacity only in the External Area to which it refers. This ensures that these imports cannot be supplied from anywhere except that Area.

3.10.6 The demand for these imports is specified in the technical coefficients of the input-output model (see Chapter 22). Note that this specification means that as these coefficients are fixed input values, the proportion of imports in the total inputs of each sector cannot be changed by the model itself. In particular, changes in the transport system will not change the ratio of imported to domestic (Scottish) inputs in any sector's consumption.

3.11 Quality change sub-model definition

3.11.1 The quality model is set up so that

- housing quality is adjusted to reflect the quality of exogenously-defined housing construction and the quality of endogenously forecast new housing
- retail quality is changed only by exogenous inputs

3.12 Activity and floorspace relationships

3.12.1 The Model Definition file specifies:

- which type of floorspace, if any, each activity uses
- which of the utility and/or cost functions controls how the activity changes its use of floorspace in response to rent changes

3.12.2 Activities not listed in the input file do not occupy modelled floorspace. The economic activities in TELMoS which do not occupy floorspace are:

- 32: Agriculture Manual
- 34: Manual fishing
- 36: Mining Manual

3.12.3 The activities that occupy each modelled floorspace type were described in Table 3-6.

3.13 Location model timelags

3.13.1 The model definition input file also specifies:

- the timelags used in the location model
- the choice of location model function and related options

3.13.2 The timelags are documented in Chapters 18 (households) and 19 (employment activities) of this report.

3.14 Accessibility measure definitions

3.14.1 These are documented in Chapter 12 of this report.

3.15 Other definitions

3.15.1 It should be kept in mind that the model definition file sets up and names different activities, but most of the information which makes them behave in accordance with those names is introduced elsewhere.

3.15.2 Important aspects of "definition" input to specific sub-models include the following:

- the "life-cycle" processes are defined by inputs to the transition model, MT12 (see Chapter 14) - it is these that define (for example) that younger households age into older households, etc
- the numbers of persons within households are defined by inputs to the employment status model, ME12 (see Chapter 20)
- whilst the definition file identifies household activities as belonging to different socio-economic levels, the corresponding differentials in incomes are input to the location model, ML12 (see Chapter 18)

4 URBAN DATABASE DEFINITIONS

4.1 Introduction

4.1.1 This Chapter documents the data contained in the urban database (ie by zone). This data is generally:

- **input** for the base year (and in some cases for previous years)
- **output** for forecast years (note that this includes **outputs** from the transport model which are **inputs** to the land-use/economic model)

There are one or two exceptions where the files contain input assumptions for future years, though most of the zonal assumptions about future change are input in the planning policy file. These exceptions are noted where they occur.

4.1.2 The following sections describe:

- the activity database file (AVZN<year><test>.dat)
- the space database file (SPZN<year><test>.dat)
- the space-activity database file (SAZN<year><test>.dat)
- the car-ownership database file (COZN<year><test>.dat)
- the development database file (DVZN<year><test>.dat)
- the travel to work database file (TTWM<year><test>.dat)
- the space-development database file (SPDV<year><test>.dat)
- the land use and transport interface file (ACCESS.def)
- the environmental database file (ENVR<year><test>.dat)
- active and passive accessibilities files (ACDZ<year><test>.dat and ACOZ<year><test>.dat)
- accessibilitiy and environmental database file (ASRV<year><test>.dat)

4.1.3 The file naming protocol is typically a four letter mnemonic followed by a two digit naming of the year and a two character test run name, as described in the previous chapter.

4.2 Activity database file

4.2.1 The main function of this file, AVZN<year><test>.DAT, is to record the number of units of each activity in each zone, i.e. the number of households and of jobs by activity.

4.2.2 For household activities, the Block AVZN01 records the numbers of persons by type (children, working adults, non-working adults and retired persons) within households of each activity in each zone.

4.2.3 For employment, the block shows

- the total number of workers by employment activity and workplace zone in the third column

- in the subsequent columns the actual/forecast number of workers by activity, zone and socio-economic level

4.2.4 The derivation of the 2012 figures for households, residents and employment is documented in Chapter 5 of this report.

4.2.5 Finally, in Block AVZN02, the Activity Database File records the number of households whose employment status has been changed by the employment status model ME12 within the year just modelled.

4.3 Space database file

4.3.1 The Space database File (SPZN<year><test>.dat) contains two blocks of data.

4.3.2 The first, SPZN01, describes the total quantity of floorspace (occupied plus vacant) in square metres, the rent in £/m^2 per week, the amount of vacant floorspace and the quality of the floorspace, for each zone and space category.

4.3.3 The second, SPZN02, contains information on the quantity of floorspace (in m^2) and the amount of permissible development. This is the total permitted but not yet used, ie the accumulated, unused allocation of permissible development. This is quantified in terms of the two development processes, brownfield and greenfield that were described in Section 3.7. If the model forecasts that all permissions for development of a particular type in a particular zone will be used as fast as they are allocated, the permitted development figures in this section of the database file will remain zero.

4.3.4 The preparation of the residential space data is documented in Section 7.3 of this report, while the preparation of the non-residential data is described in Section 7.4

4.4 Space-activity database file

4.4.1 The space-activity database file, SAZN<year><test>.dat relates the model activities (the 20 household types and 24 of the 27 employment categories) to the space they occupy. It defines:

- the utility of consumption (defined as £ per household per week)
- density for households and employment activities (defined as either households or jobs per $m^2$of floorspace)
- the consumption of other goods and services (defined as £ of consumption per week) for household activities only

4.4.2 The preparation of the space-activity data in relation to both household and employment activities is documented in chapter 5.

4.5 Car ownership database file

4.5.1 The car ownership database file, COZN<year><test>.dat contains zone-level data on the proportion of each household activity within each of the three car ownership categories: no car, 1 car and 2+ cars (see Table 3-9). The three values always sum to one.

4.5.2 Employment activities do not have car ownership and are omitted from the file.

4.5.3 The calculation of the base-year car-ownership proportions is documented in Chapter 5.4 of this report.

4.6 Development database file

4.6.1 The file DVZN<year><test>.dat records the amount of development (in m^2) which is under construction in each zone at the end of each one year period. The data is classified by the development process as specified in the model definition file and by the year in which it will be completed (and hence available to activities for occupation).

4.7 Travel-to-work database file

4.7.1 The main travel-to-work database files in TELMoS are the TTWM<year><test>.DAT files. These contain the zonal travel-to-work matrix, disaggregated by car ownership and socio-economic level. They show the number of people living in one zone and working in another. In forecasts years (ie all years other than 2012) these are output by the employment status model ME12.

4.7.2 Note that in these files, the socio-economic level is that of the individual workers, not that of the households to which they belong. The destination (workplace) totals are therefore directly comparable and consistent with the data for workers by workplace and socio-economic level, summed over employment activities. The origin (home) totals are comparable and consistent with the data on working adults by home zone and car ownership, but are not directly comparable with the breakdown by household and socio-economic level.

4.8 Space-development database file

4.8.1 The space-development database file, SPDV<year><test>.dat contains the total amount of unconstrained development for each floorspace category within the Fully Modelled Area. The data is classified by the floorspace category as specified in the model definition file and defined in terms of m^2 of floorspace. The preparation of this data is documented in Section 7.2 of this report.

4.9 Land-use/transport interface database file

4.9.1 The land-use/transport interface database file specifies exogenous weights for use in the accessibility calculations in AC12 (described in Chapter 122 of this report).

4.10 Environmental database file

4.10.1 DELTA allows for environmental data to feed back from the transport model (or, in principle, a wider environmental model taking account of transport and other impacts) as an influence on the location of residents (and, again in principle, of businesses).

4.11 Active and passive accessibilities by measure

4.11.1 The ACOZ<year><test>.DAT and ACDZ<year><test>.DAT files hold the accessibility measures output by program AC12 grouped into:

- active accessibilities, which are a measure of how easily people located in zone *i* can get to “opportunities” (eg for work, for shopping) given the numbers of such opportunities in every zone *j* and the generalised costs of travel from *i* to each *j*

- passive accessibilities, which are a measure of how easily opportunities in zone *j* can be reached by people (potential workers, potential shoppers) who might come from each zone *i*, given their distribution across the zones *i* and the generalised costs of travel from each *i* to *j*

4.11.2 These accessibility measures relate to a specific set of opportunities and a specific set of generalised costs (eg off-peak, non-work travel). These are input to program IA12 which combines them into measures of accessibility by activity (see section 12.4).

4.12 Accessibility and environmental values by activity

4.12.1 The file ASRV<year><test>.DAT contains the information about transport-related variables in the main forms in which they are used by the land-use model. They include information on:

- accessibility by activity and (for households) car-ownership level
- zonal environment quality by activity (distinct from the area environmental quality, which is used in the migration model)

4.12.2 Accessibility is derived from the generalised costs. In this file the values represent a weekly calculation that is based upon the ACOZ and ACDZ files (see section 4.11) and scaled up by the number of trips per week.

5 HOUSEHOLD AND EMPLOYMENT DATA

5.1 Introduction

5.1.1 A range of information sources have been used to assemble this data. The household database had been sourced from the General Register of Scotland (GROS) and 2011 Census release data from Scotland's Census (scotlandscensus.gov.uk). The source of the employment data was the Business Register Emplyer Survey (BRES). The processes in the data creation involved:

- taking data from the different sources
- converting the data from the sources' definitions to those used within the TELMoS land use model
- converting the data from the geographical areas used in the source to the TELMoS zones
- ensuring that the final figures are consistent and match the data source at regional and/or national level

5.1.2 TELMoS12 was prepared at a point in time when there was only a limited release of 2011 Census data. Headline local authority level was published, however none of the small area cross-tabulation information that would provide zone-level inputs to the model were available. Rather than dispense with the Census data that had been released we have tried to apply it, where appropriate, as a higher (district) level constrain.

5.2 The Household Population Database

5.2.1 2011 Census data was available only at the Local Authority level. The household Table 17 from the census 2011 release version 1 contained data on

- total households by local authority
- usual residents of households
- average household size by council area

Processing the source data

5.2.2 The TELMoS base-year database requires information on the numbers of households by each of the 20 household types, described in Chapter 3, for each zone. As this level of information was not available from the limited 2011 Census material that had been released, the distribution of households by type and zone that were forecast in the TELMoS07 do minimum test has been used as a starting point for creating the new database.

5.2.3 A scaling factor has then been applied to this zone level data. This was derived by comparing the TELMoS07 do minimum 2011 forecast of households by local authority area with the 2011 Census figure. The district-level scaling factor was then applied to the zone-level data within that authority area.

5.2.4 Table 5-1 shows the 2011 Census and TELMoS07 2011 forecast of households. At a national level there was a 23,000 difference in the number of households. This represents a 1% difference. At a Local Authority level the differences range from -7% in Clackmannanshire to 6.8% in Inverclyde.

Table 5-1 Comparison of 2011 Census and TELMoS07 Do Minimum 2011 forecast

Local Authority	2011 Census number of households	TELMoS07 Do Minimum reference case number of households in 2011	difference	Difference %
Dumfries & Galloway	**67,980**	71,058	- 3,078	-4.5%
Scottish Borders	**52,500**	52,791	- 291	-0.6%
East Lothian	**42,910**	43,127	- 217	-0.5%
Midlothian	**34,980**	35,803	- 823	-2.4%
City of Edinburgh	**223,050**	223,693	- 643	-0.3%
West Lothian	**73,400**	73,265	135	0.2%
South Lanarkshire	**139,190**	140,239	- 1,049	-0.8%
East Ayrshire	**5,3920**	55,069	- 1,149	-2.1%
South Ayrshire	**51,290**	52,642	- 1,352	-2.6%
North Ayrshire	**62,500**	62,689	- 189	-0.3%
East Renfrewshire	**37,210**	36,202	1,008	2.7%
City of Glasgow	**285,690**	290,888	- 5,198	-1.8%
North Lanarkshire	**146,000**	147,081	- 1,081	-0.7%
Falkirk	**68,730**	71,229	- 2,499	-3.6%
East Dunbartonshire	**43,480**	43,743	- 263	-0.6%
Renfrewshire	**80,910**	82,933	- 2,023	-2.5%
Inverclyde	**37,440**	34,912	2,528	6.8%
West Dunbartonshire	**42,170**	42,562	- 392	-0.9%
Stirling	**37,570**	39,412	- 1,842	-4.9%
Clackmannanshire	**22,730**	24,332	- 1,602	-7.0%
Fife	**160,950**	163,867	- 2,917	-1.8%
Perth & Kinross	**64,780**	65,275	- 495	-0.8%
City of Dundee	**69,190**	68,344	846	1.2%
Angus	**51,620**	49,865	1,755	3.4%
Aberdeenshire	**104,710**	101,925	2,785	2.7%
City of Aberdeen	**103,370**	108,792	- 5,422	-5.2%
Moray	**40,060**	39,314	746	1.9%
Argyll & Bute	**40,130**	42,841	- 2,711	-6.8%
Highland	**102,090**	101,026	1,064	1.0%
Eilean Siar	**12,580**	12,098	482	3.8%
Orkney Islands	**9,730**	9,255	475	4.9%
Shetland Islands	**9,950**	9,851	99	1.0%

Local Authority	2011 Census number of households	TELMoS07 Do Minimum reference case number of households in 2011	difference	Difference %
SCOTLAND	**2,372,810**	**2,396,125**	**- 23,315**	**-1.0%**

5.2.5 This scaling is applied to each of the household types described previously in Table 3-4.

5.2.6 Table 5-2 provides compares a disaggregation of the total number of households within the TELMoS12 database, based upon this approach, with the GROS 2010 household forecasts for 2011. The GROS data contains a more limited set of five household categories. It is possible to aggregate the TELMoS household categories to these. The 'fit' between the GROS data and TELMoS12 is reasonably good: there are proportionally more single person and single parent households within TELMoS12 then the GROS estimate, conversely there are proportionally fewer three adult households.

Table 5-2 Comparison of the TELMoS12 2011-Census based households with GROS 2010-based household forecasts.

	Telmos12 - (2011 Census)	2010 GROS targets
single person households	37.0%	36.6%
single parent households	7.2%	7.0%
two adults no children	30.5%	30.5%
three adults no children	7.9%	8.0%
two/three adults with children	17.3%	17.8%

5.2.7 The TELMoS12 database also includes estimates of population by the four age groups described in Table 3-5. These were updated and constrained so as to be consistent with the 2011 Census local authority level population estimates. This process involved:

- extracting population data from the 2011 Census Table A1
- aggregating the finer Census age ranges to the four age groups within TELMoS, this involved proportioning the 15-19 age band between the 0-15 and the 16- 74 working age population on a 20:80 basis
- calculating the residential population within each TELMoS age group by applying the ratios of population in residential and communal establishments contained within 2011 Census table A18
- dividing the working age population into working and non-working based upon the proportions within the TELMoS07 Do-Minimum test. This source was used in the absence of any 2011 Census output or similar below Local Authority level.

5.2.8 This Census-based estimate of population, by age group, was compared to the previous TELMoS07 Do-Minimum population estimates in order to create scaling factors. These were applied to the zone-level population within each district to adjust the TELMoS07 population to be consistent with the 2011 Census. Table 5-3 shows a comparison of the 2011 Census and the TELMoS07 population for each authority area.

Table 5-3 Comparison of 2011 Census and TELMoS12

Local Authority	2011 census				TELMoS			
	0-15	16-64	65+	Total	children	Work-ing age	retired	Total
Dumfries & Galloway	24,828	92,108	32,564	149,500	25,627	92,261	32,436	150,324
Scottish Borders	18,961	69,912	23,627	112,500	19,506	69,523	23,229	112,257
East Lothian	18,225	62,013	17,362	97,600	15,617	57,492	18,073	91,182
Midlothian	15,570	52,981	13,750	82,300	12,450	50,759	14,408	77,616
City of Edinburgh	71,295	324,660	66,445	462,400	80,534	306,311	88,803	475,648
West Lothian	34,957	114,887	23,555	173,400	31,162	106,783	24,322	162,268
South Lanarkshire	55,055	203,201	52,344	310,600	52,735	194,922	55,741	303,399
East Ayrshire	21,376	78,885	21,040	121,300	21,068	76,110	23,656	120,834
South Ayrshire	18,136	69,188	23,977	111,300	19,406	68,819	25,147	113,371
North Ayrshire	24,095	86,786	25,618	136,500	23,719	84,775	27,632	136,126
East Renfrewshire	17,802	56,107	16,292	90,200	14,837	51,411	15,919	82,167
City of Glasgow	94,820	403,356	80,024	578,200	114,918	396,324	118,445	629,686
North Lanarkshire	64,519	221,040	50,142	335,700	57,830	209,832	57,554	325,216
Falkirk	28,132	101,061	25,107	154,300	26,705	96,498	28,109	151,312
East Dunbartonshire	18,593	65,624	20,383	104,600	17,222	61,961	19,745	98,928
Renfrewshire	30,373	113,198	29,129	172,700	29,561	113,942	32,787	176,290
Inverclyde	13,517	52,099	14,483	80,100	12,497	45,877	15,059	73,433
West Dunbartonshire	15,936	59,379	14,785	90,100	16,319	57,903	17,847	92,070
Stirling	15,333	55,624	14,743	85,700	14,933	54,678	16,064	85,676
Clackmannanshire	9,158	33,201	8,040	50,400	9,717	32,851	9,369	51,936
Fife	63,259	231,310	62,731	357,300	61,629	221,175	68,522	351,325
Perth & Kinross	24,272	89,335	28,693	142,300	24,792	86,853	29,856	141,501
City of Dundee	23,307	94,963	23,731	142,000	25,407	90,516	31,799	147,722
Angus	20,018	71,681	22,801	114,500	18,213	66,285	22,677	107,175
Aberdeenshire	46,793	163,310	40,298	250,400	41,345	147,236	39,154	227,734
City of Aberdeen	31,764	151,572	30,764	214,100	40,139	151,995	40,913	233,047
Moray	16,597	57,690	16,812	91,100	15,791	53,911	16,850	86,553
Argyll & Bute	13,914	52,936	18,850	85,700	15,936	55,658	20,007	91,600
Highland	40,486	145,519	42,395	228,400	37,584	135,742	42,134	215,460

Local Authority	2011 census				TELMoS			
	0-15	16-64	65+	Total	children	Working age	retired	Total
Eilean Siar	4,553	16,932	5,815	27,300	4,335	15,598	5,836	25,769
Orkney Islands	3,526	13,313	4,061	20,900	3,343	12,348	3,741	19,432
Shetland Islands	4,441	14,691	3,668	22,800	3,843	13,539	3,469	20,851
SCOTLAND	903,612	3,418,559	874,029	5,196,200	908,718	3,279,886	989,305	5,177,910

5.2.9 Table 5-4 shows the comparison of 2011 age category and the DELTA person type applied within TELMoS12.

Table 5-4 Correspondence between 2011 Census age groups and TELMoS12 person types

Census Person Type	DELTA Type
Dependent Children 0 to 15	Child
Working persons aged 16 to 74 working	Worker
Persons aged 16 to 74 not working, excluding retired & dependent children	Non-Worker
Retired persons aged 16 to 74 - Persons aged 75 and over	Retired

5.3 EMPLOYMENT DATABASE

5.3.1 The Employment database contains information for the numbers of jobs within each zone within each of the 26 Urban Economic Activities shown in Table 3.10. The main source of information used, when preparing TELMoS07 and earlier versions of the model was the 2001 Census. The Census and TELMoS apply the same definition of employment.

5.3.2 The early 2011 Census releases did not include any information on employment by workplace. We have therefore looked to other sources, in particular the BRES database. This contains workplace data at Datazone level. As the TELMoS zones are aggregations of one or more datazone the BRES data provides a convenient source for generating TELMoS Zone level employment data.

5.3.3 One limitation of the BRES is that it adopts a different definition of employment to that used within TELMoS (ie a Census-based definition). The key differences are:

- it excludes the self employed
- it records jobs at the workplace and not persons in employment (as per the Census

5.3.4 A scaling factor has been applied to adjust the BRES so that it is consistent with the Census definition. This was based upon March 2012 national estimates of the number of people in employment and the number of employees in the BRES taken from the BRES Regional Summary on the ONS website. This scaling factor had a value of 0.945.

Processing data

5.3.5 The processing of the BRES data to create Base Year Data at TELMoS zone and by TELMoS economic activity involved the following steps:

- the BRES datazone level data was aggregated to TELMoS12 zone
- the zone level data was converted from BRES economic sector to TELMoS economic activity using the correspondence shown in Table 5.5
- where economic sectors were split within TELMoS into non-manual and manual (for example Activities 31 and 32 which split the manual and non-manual components of Agriculture, Hunting and Forestry) then the split in TELMoS07 (which was based upon the 2001 Census) was applied.

Table 5-5 Correspondence of BRES employment sectors and TELMoS Employment Activities

TELMoS activity		TELMoS Employment activity description	SEL	Floorspace	BRES Employment sectors
31	A	Agriculture, hunting and forestry	Non-manual	3	A : Agriculture, forestry and fishing
32	A	Agriculture, hunting and forestry	Manual	-	A : Agriculture, forestry and fishing
33	B	Fishing	Non-manual	3	A : Agriculture, forestry and fishing
34	B	Fishing	Manual	-	A : Agriculture, forestry and fishing
35	C	Mining and quarrying	Non-manual	3	B : Mining and quarrying
36	C	Mining and quarrying	Manual	-	B : Mining and quarrying
37	D	Manufacturing	Non-manual	3	C : Manufacturing
38	D	Manufacturing	Manual	4	C : Manufacturing
39	E	Electricity, gas and water supply	Non-manual	3	D : Electricity, gas, steam and air conditioning supply E : Water supply; sewerage, waste management and remediation activities
40	E	Electricity, gas and water supply	Manual	4	D : Electricity, gas, steam and air conditioning supply E : Water supply; sewerage, waste management and remediation activities
41	F	Construction	Non-manual	3	F : Construction
42	F	Construction	Manual	4	F : Construction
43	G	Wholesale & retail trade, repairs - *RETAIL*	Manual and Non-manual	2	G : Wholesale and retail trade; repair of motor vehicles and motorcycles
45	G	Wholesale & retail trade, repairs - *OTHER*	Non-manual	3	G : Wholesale and retail trade; repair of motor vehicles and motorcycles
46	G	Wholesale & retail trade, repairs - *OTHER*	Manual	4	G : Wholesale and retail trade; repair of motor vehicles and motorcycles
47	H	Hotels & restaurants	Manual and Non-manual	5	I : Accommodation and food service activities
48	I	Transport, storage & communications	Non-manual	3	H : Transportation and storage J : Information and communication
49	I	Transport, storage & communications	Manual	4	H : Transportation and storage J : Information and communication
50	J	Intermediaries – FINANCIAL MANAGENT	Manual and Non-manual	3	K : Financial and insurance activities
51	J	Intermed. – LOCAL FINANCIAL SERVICES	Manual and Non-manual	3	K : Financial and insurance activities
52	K	Real estate, renting & business activities	Manual and Non-manual	3	L : Real estate activities M : Professional, scientific and technical activities
53	L	Public administration, defence, social security	Non-Manual	3	O : Public administration and defence; compulsory social security
54	L	Public administration, defence, social security	Manual	4	O : Public administration and defence; compulsory social security

TELMoS activity		TELMoS Employment activity description	SEL	Floorspace	BRES Employment sectors
55	M	Education	Manual and Non-manual	6	P : Education
56	N	Health	Manual and Non-manual	7	Q : Human health and social work activities
57	O	Other	Non-manual	3	S : Other service activities R : Arts, entertainment and recreation
58	O	Other	Manual	4	S : Other service activities R : Arts, entertainment and recreation

5.3.6 Employment at the four airport zones (Edinburgh, Glasgow, Aberdeen and Prestwick) and the RBS headquarters are treated differently in the employment database creation. The approach is described in the following section. This different approach does not affected the total number of jobs within Scotland in the 2012 database.

Airports and RBS employment

5.3.7 There are dedicated zones within TELMoS for the four airports airport and the RBS headquarters. These zones do not have any correspondence with the Datazone geography that was used in defining the other TELMoS zones. These zones typically lie within larger TELMoS zones.

5.3.8 The employment data for the airports in 2011 has been taken from the Airport's Masterplans. These indicate that Edinburgh and Aberdeen have around 2,500 airport jobs, Prestwick 2,000 jobs whilst Glasgow airport has 5,000 jobs.

5.3.9 These numbers of jobs have been subtracted from the BRES-derived data for the surrounding 'parent' TELMoS zone and assigned to the Airport zone.

5.3.10 The RBS headquarters (Zone 67) is treated in the same manner. It is a small zone that lies within a larger zone and represents the Headquarter office campus. According to the RBS website there were 3,250 jobs on the site in 2012. We have applied that number to the RBS zone and deducted the same amount from the BRES-derived data for the surrounding 'parent' TELMoS zone.

5.4 <u>The Car Ownership database</u>

5.4.1 The DELTA car-ownership database (COZN file) contains, for every zone and activity pair, the proportion of households within each of the car-ownership levels.

5.4.2 Within TELMoS12 a household will have one of three car ownership levels, namely:

- no car
- one car
- two cars or more

5.4.3 Information on car-ownership was available for 2001 by DELTA household type and ward in the customised Census table commissioned by DSC. This data was converted to TELMoS zone using a lookup table. Car ownership proportions for 2001 were then calculated by household type and zone.

5.4.4 The 2001 COZN file was then scaled to 2007 (in the TELMoS07) using national statistics of car ownership.

5.4.5 District level data from the 2011 Census has then been used to create an interim 2011 Car Ownership database. The Census values having been used to scale the TELMoS07 2011 car ownership database.

The Outputs

5.4.6 The output of this process was the creation of a base year file of car ownership date, COZN.

5.5 Creating a 2012 Database

5.5.1 The previous sections have drawn upon 2011 Census data and other sources. The steps taken to create a 2012 database, based upon this data, are described in Chapter 9.

6 REGIONAL ECONOMIC MODEL DATABASE

6.1 Introduction

6.1.1 The Regional Economic Model (REM) database forecasts the growth (or decline) of the sectors of the economy in each of the DELTA Areas modelled. Its inputs include forecasts of overall growth in output and productivity. The forecasts by sector and area are influenced by:

- costs of transport (from the transport model)
- consumer demand for goods and services (from the urban model)
- commercial rents (from the urban model).

6.1.2 The base year database draws on the most recently published economic statistics. In particular the Industry by Industry Matrix for 2009 contained within the Scottish Government Statistics publication 'Scottish Supply Use and Analytical Input-Output Tables, 1998-2009'[1]. This table contains information on the intermediate demand for each sector, final consumption demand (from households and government) and Exports.

6.1.3 The 2009 REM data from the table above is converted into the TELMoS12 base year data by running the Trade and Production model programs using estimated Final demands. The processes involved are discussed in the Employment Scenario in Chapter 9.

6.1.4 The description of the REM database and files are reported below.

6.2 Definitions

6.2.1 Chapter 3 defines the REM sectors and their correspondence with the employment activities in the urban model. Table 3-11 describes the REM sectors that define import sectors.

6.3 Consumer final demand

6.3.1 Consumer final demand by sector and area is generated by running PX12. This reads the unrban model's outputs on consumer expenditure by household type and zone and converts this into consumer final demand by sector and area.

6.3.2 For this it requires the AVZN activity database and the SAZN space-activity data from the urban model. The AVZN database contains information on the numbers of households by type, the SAZN database contains information on the relationship between activity and floorspace including the cost of consumption (of floorspace) and the floorspace occupied by each household type.

6.3.3 It also requires the MP12 input file to contain the following data:

- MPCND: Consumer Final demand by Sector
- MPIN01: Mark-up on costs; value added
- MPIN03: Input-output technical coefficients

[1] http://www.scotland.gov.uk/Topics/Statistics/Browse/Economy/Input-Output/Downloads/IO1998-2009IxI

6.3.4 The consumer demand by sector and Input-Output coefficients were calculated directly from the 2009 Industry and Industry input-output table.

6.4 Capacities

6.4.1 The Capacity data file contains capacity data by area and sector. These capacities were calculated by aggregating the activity database file matching zones to areas and employment activities to REM sectors (using the matching in Chapter 3.

6.5 Exports and Government Expenditure

6.5.1 The ARFD<><>.dat file details the final demand from exports and government expenditure by area. The figures in the 2009 file are taken directly from the 2009 Industry by Industry input-output table.

6.6 Generalised Costs

6.6.1 The REM also requires generalised costs by area and sector. In order to generate these, two programs are run. These take the costs provided to us by the transport model (which are by zone and purpose) and convert them costs by area and purpose, this data is then used to create a matrix of costs by area and REM sector.

6.7 Area distances

6.7.1 MMDS0900.DAT contains the distances between the model areas. This information remains unchanged; the same inter-area distrances that were applied in TELMoS07 are used.

6.8 Costs of Production

6.8.1 The ARCS<><>.dat file contains information on costs of production by sector and area, specifically:

- production price
- consumption cost
- consumption transport cost
- production labour cost
- production space cost

6.8.2 This file is generated by running program PC12. Its calculation is based upon the inter-area distances, the trade matrix file, the production file, the inter-area cost files and the data on capacity y sector and area.

6.9 Production, Value Added and Consumption

6.9.1 The MPPR0900.dat file contains 2009 production, value added and consumption values by sector and area, this is generated by running the MP12 program on the files listed above.

6.10 Trade volumes

Trade volumes by sector between production and consumption areas for 2009 have been generated by running MP12 for the base year. They are stored in MPTR0900.dat.

6.11 Creating a 2012 database

6.11.1 The previous sections have drawn upon 2009 input-output tables. The steps taken to create a 2012 database, based upon this data, are described in Chapter 9.

7 PROCESSING OTHER DATABASE FILES

7.1 Introduction

This chapter describes the other database files which were created in 2011 for TELMoS12. It documents the processes involved in creating the database.

7.2 Space database file

7.2.1 Floorspace is a fundamental component in the DELTA model as it provides an indication of the capacity of zones in terms of their ability to accommodate households and employment.

7.2.2 DELTA uses rents as the mechanism by which activities (households or employment) compete for and allocate floorspace. The interaction between supply and demand, within a DELTA run will determine future rents.

7.3 Residential floorspace

7.3.1 The residential floorspace database requires information on floorspace, rent levels and residential quality.

7.3.2 The calculations of floorspace are derived from the 2011 Council tax dwelling stock database[2]. This contains dwelling stock records by house type at Datazone level. The conversion of this to residential floorspace required:

- the aggregation of datazone-level data to TELMoS zones;
- an average floorsize per dwelling types (detached, terraced, semi-detached and flat) was used to convert the dwellings into floorspace. This calculation applied the same average floorspace per dwelling assumptions as was used in TELMoS07 and was based upon Nationwide Building Society data (see Table 7.1).

7.3.3 This process creates a figure for total residential floorspace by TELMoS zones.

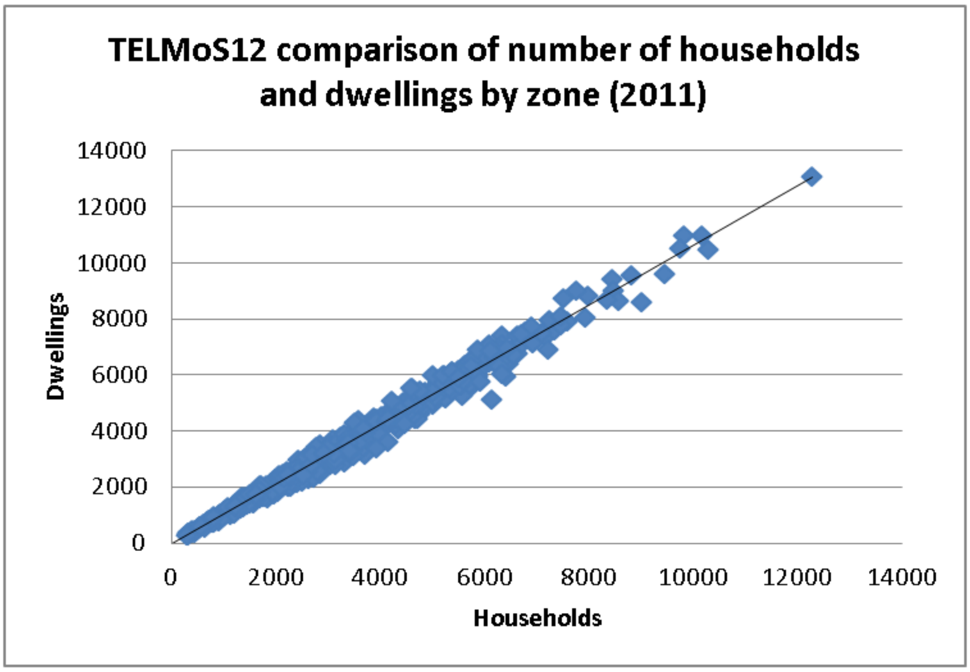
Table 7-1 Average Floorspace per Dwelling by Dwelling Type

Type	m^2
Detached	145
Terraced	90
Semi-detached	110
Flat	60

7.3.4 The total residential floorspace was compared against the total households per zone to ensure there is a reasonable floorspace per household ratio. Figure 7-1 shows the match between the two separately compiled sources.

[2] 2011 Council tax dwelling data, (Scottish neighbourhood statistics website).

Figure 7-1 Comparison of TELMoS12 estimate of households and dwellings derived from Council Tax data (by zone)



Rent calculations

7.3.5 TELMoS12, like previous versions of the TELMoS model applies values of rent defined in terms of weekly rent per unit of floorspace (ie $1m^2$).

7.3.6 The rents are based on the 2011 average house prices in the Scottish districts. This house price data based upon Registers of Scotland Executive Agency data. All figures are simple averages based on all residential properties between £20,000 and £1,000,000 recorded in the four quarters of each year. The district average house prices are presented in Table 7-2, below.

Table 7-2 Average house prices – 2011

AREA	Average Price (£)
Clackmannanshire	115,825
Dumfries & Galloway	129,169
East Ayrshire	107,593
East Dunbartonshire	215,300
East Lothian	182,889
East Renfrewshire	212,540
Eilean Siar	100,829
Falkirk	121,292
Fife	133,515
Highlands	152,432
Inverclyde	127,410
Midlothian	159,821
Moray	145,567
North Ayrshire	108,021
Orkneys	117,358
Perth & Kinross	179,109
Scottish Borders	163,395
Shetlands	120,005
South Ayrshire	141,690
South Lanarkshire	124,502
Stirling	183,662
City of Aberdeen	196,175
Aberdeenshire	205,786
Argyll & Bute	146,804
City of Edinburgh	212,607
Renfrewshire	108,345
West Dunbartonshire	117,336
West Lothian	138,952
Angus	153,451
City of Dundee	127,622
City of Glasgow	129,191
North Lanarkshire	112,175

7.3.7 The average rent for a zone was calculated using the following formula:

rent = (house price x 0.07 (7%) / 52 (weeks in year))/ average residential dwelling size

7.3.8 This assumes a 7% annual yield. The division by 52 converts the yearly rents into weekly rents.

Housing Quality

7.3.9 The housing quality coefficients relate to the quality of the residential stock within each zone. These have remained unchanged from the values applied in TELMoS07.

7.4 Creation of the Employment Floorspace Database: Commercial Floorspace

7.4.1 This section describes the methodology for creating the floorspace databases for retail, office, industrial and warehousing floorspace. The approach is similar to that applied when creating TELMoS07 and reflects the limited published data on commercial floorspace.

7.4.2 As there is no commercial floorspace available at small area level, estimates of floorspace have been derived from the combination of the employment database described in Chapter 5 and information on floorspace per worker.

7.4.3 The employment densities are based upon the floorspace per worker statistics contained within "Employment Densities: A Full Guide, July 2001". This was prepared by Arup Economics and Planning and published on behalf of English Partnerships and the RDAs. The work by Arup provides a range of employment densities, expressed as sq m per worker. The average densities for each commercial space category are presented in the first row of Table 7-3.

7.4.4 A variation in densities has been applied to reflect the different worker to floorspace densities within City Centres. A similar approach was applied to that used in TELMoS07 for this calculation. The second and third rows of Table 7-3 show the densities for city centres and other areas. Figure 7-3 shows the location of the zones where the 'city zone' densities have been applied.

Figure 7-2 Location of the City Centre Zones where higher floorspace to worker densities applied

TELMoS12

Location of zones where City Centre densities applied

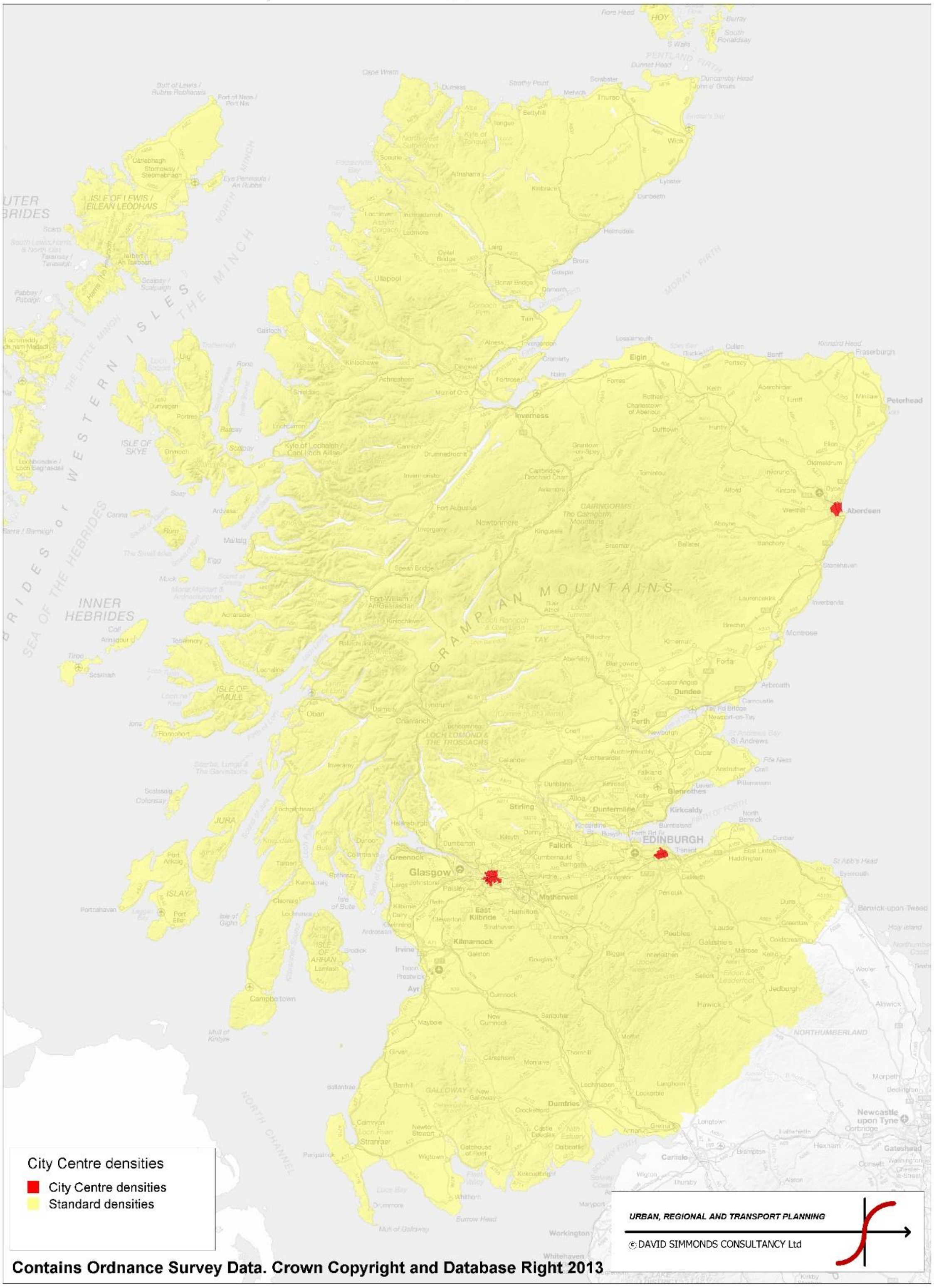


Table 7-3 Average floorspace per worker

	Retail	Office	Industrial	Warehouse	Hospitality	Education	Health
Average Flsp (sqm) per Wrk	40	18.5	32	62	40	40	40
Estimated City centre	34.3	14.8	25.6	49.6	34.3	32	32
Estimated Other areas	45.7	22.2	38.4	74.4	45.7	48	48

7.4.5 The commercial floorspace for each category and each zone is derived by applying the densities to the number of jobs within the zone.

7.4.6 The vacancy rates in Table 7-4 have been applied to the total floorpsace to calculate the quantity of vacant floorspace within each zone. This amount has then been added to the previous calculation of (occupied) floorspace to give a figure for the total floorspace within each zone.

Table 7-4 Vacancy rates

Flsp	Vacancy rate
2- Retail	0.05
3- Office	0.05
4- Industry	0.2
5- Leisure/ Hotel	0.01

Commercial Rents

7.4.7 TELMoS12 requires rents for each floorspace type and for each zone. The key source of rental data is the Valuation Office Agency's Property Market Report[3]. This provides information on rent levels within Edinburgh, Glasgow and Aberdeen. In particular it provides data for:

- Retail - Standard shop unit per Square metre Zone A
- Retail - Modern non -food warehouse
- Office - Self contained office suite over 1000 sqm £ per sqm
- Industrial- Small starter/nursery unit 50-200 square metres £ per square metre
- Indutrial - Industrial/warehouse unit circa 1000-3000 square metres £ per square metre

7.4.8 The first step in processing this data was convert annual rentals to weekly. This is required to ensure that the rents are represented in a form that is consistent with the other rent-based calculations within TELMoS. For the industrial and office rents this was a straightforward division of the annual rent by 52.

7.4.9 The second step was to calculate the retail rents for each zone. This involved the following:

- Calculation of a zone rental within the City Centre zones. The Zone A rentals refer to the rent associated with the shop frontage and the first 6.1

[3] http://www.voa.gov.uk/dvs/_downloads/pmr_2011.pdf

metres of retail floorspace. Schiller[4] implies an average shop rent for a 2000 sq ft retail unit of 55% of the Prime A rental value. We have then multiplied this rent by 0.6 to take account of the mix of prime and non-prime retail floorspace within a zone. This calculation has been used for retail rents within the central zones within Edinburgh, Glasgow and Aberdeen (see Fig 7-4).

- Calculation of a zone rental for other parts of Edinburgh, Glasgow and Aberdeen is based upon the VOA non-Zone A retail rents within those cities.
- Calculation of zone rentals within other districts is based upon the ratio of TELMoS07 retail rents within Edinburgh, Glasgow and Aberdeen to the rent within the zone (and district) in question. Zones were compared to either Edinburgh, Glasgow, Aberdeen or a combination of the three. The comparator source for each zone is shown in Figure 7-5. This ratio or scaling factor is then applied to the non-Zone A retail rents within the city (cities) in question.
- A variation to this approach has been applied to the City Centre zones within Stirling, Perth and Dundee (Zones 466, 539 and 555). In these zones the scaling has been applied to the city centre rents rather than the Non-Zone A rents.

[4] Schiller, R (2001): *The dynamics of property location*. Spon, London.

Figure 7-3 City Centre zones where retail rents based upon modified Zone A rent data

TELMoS12

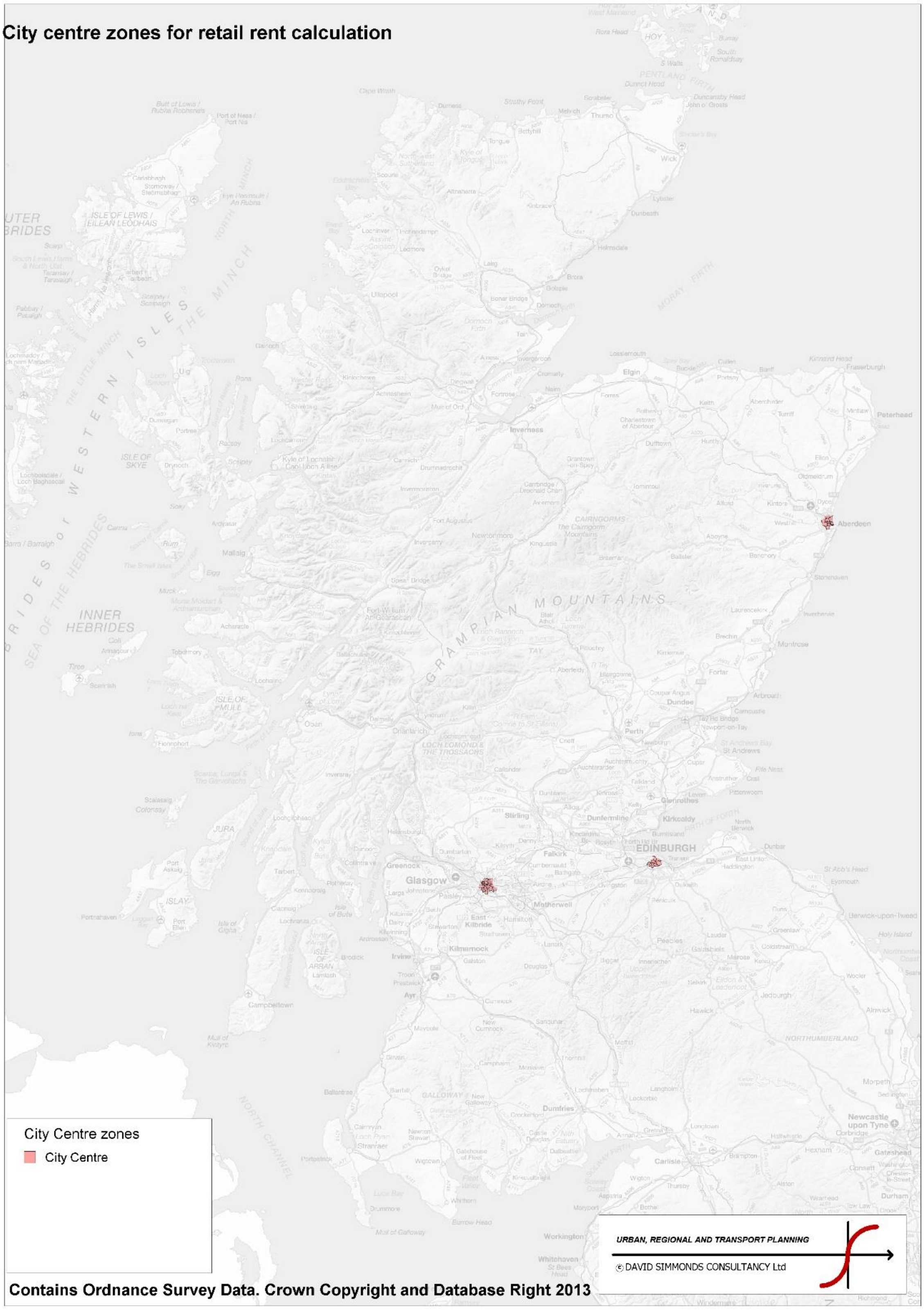
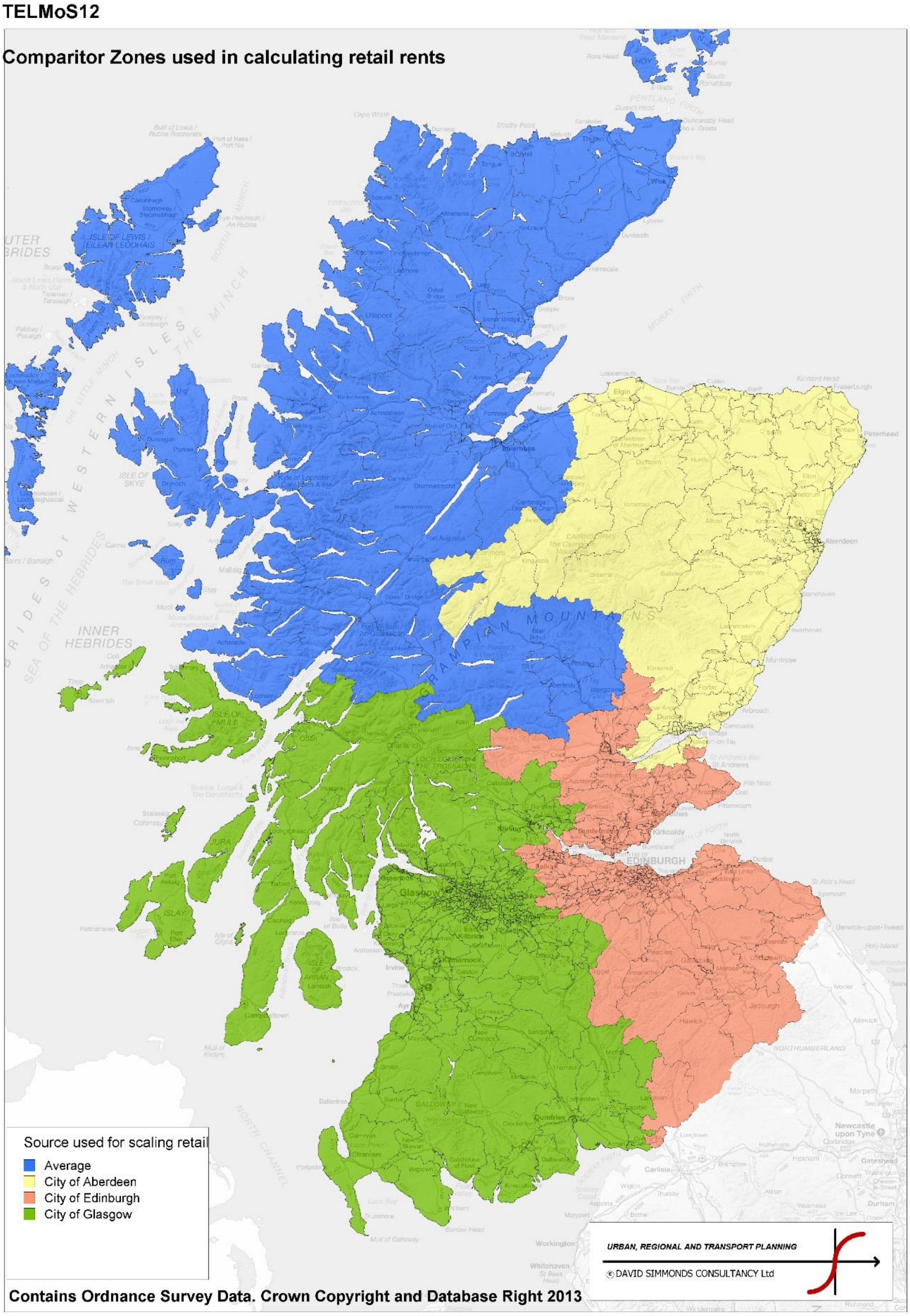


Figure 7-4 Comparitor rents used in calculating retail rents



7.4.10 The industrial rents reported in the VOA Property report differentiates between small industrial units and larger inedustiral/warehouse units. This information is available for Edinburgh, Glasgow and Aberdeen. Within TELMoS12 there is only one space category that covers industrial and warehouse related activity. The following steps weight the rent according to the split of activities (between industrial and warehousing) that would have been applied the two land uses were modelled separately:

- Identify the proportions of TELMoS12's economic activity that would use industrial and warehoure floorspace and calculate the number of jobs locating in industrial and warehouse floorspace. Table 7-5 shows the economic activities that are assumed to be associated with each of these two types of land use.
- Calculate the industrial and warehouse related floorspace by multiply the total jobs by the flsp per worker[5].
- Calculate the rent by applying the rent levels for small starter/nursery units (from the VOA report) to the industrial floorspace and the industrial/warehouse rents to the warehouse floorspace, then calculating a weighted average rent.

7.4.11 For the industrial rents there was no differentiation applied between City Centre zones and the rest of the local authority areas.

7.4.12 Rent levels in zones in other districts (ie not in Edinburgh, Glasgow and Aberdeen) were calculated in a similar way to that described above for retail rents. The ratio of TELMoS07 industrial rents in the major cities was compared to that in the other authorities and a scaling factor calculated. This was then applied to the rents in the major centre in order to arrive at a rental level for zones in the other authorities.

Table 7-5 Split of industrial activities between those occupying industrial and warehouse floorspace

Economic Activity	Description	Land Use
38	Manufacturing - manual	Industrial
40	Electricity, Gas and Water Supply - manual	Industrial
42	Construction -manual	Industrial
46	Wholesale and retail trade, repair – manual	Warehouse
48	Transport storage and communications - manual	Warehouse
54	Public Admin - manual	Industrial
58	Other Services -manual	Industrial

[5] Floorspace per worker based upon published material Source: http://www.wiltshire.gov.uk/wiltshire-workspace-and-employment-land-strategy-appendix-6-employment-and-development-densities.pdf

7.4.13 For office rents, the VOA values for Edinburgh, Glasgow and Aberdeen, which represent City Centre rent levels were applied to the City Centre zones that were previously described when reviewing the calculation of retail rents.

7.4.14 For other zones within the City of Edinburgh, Glasgow City and Aberdeen a scaling factor was calculated based upon the TELMoS07 average office rent in the City Centre zones and the other zones within the authority area. This scaling factor was applied to calculate the rent level in the other zones.

7.4.15 A similar scaling exercise was applied when calculating the office rental in zones in other local authority areas.

7.4.16 Rents for Leisure and Hotels (Space Category 5) were assumed to be similar,within each zone, to the retail rents described previously.

7.4.17 Rents for Education and Health (space categories 6 and 7) have been calculated as an average of the Spct 6 and 7 rents in TELMoS07, hence all the zones have the same value for spct 6 and 7.

8 AREA LEVEL FILES

8.1 Introduction

8.1.1 This chapter describes the main Area level files. These are shown in Table 8-1.

Table 8-1 Area level files

File	Content
ARAC1100.dat	Area Accessibility Values
ARCP1100.dat	Capacity by sector and area
ARCS1100.dat	Space Costs by sector and area
AREN1100.dat	Area environmental values
ARFD1100.dat	Measure of Demand
MMDS1100.dat	Matrix of distances between areas
ARMC1100.dat	Generalised Cost Matrices by sector
ARMX01100.dat	Generalised Cost Matrices by purpose

8.2 Area accessibility values

8.2.1 The area accessibility file ARAC1100.dat is calculated by running program AA12. It generates area-level accessibilities. These are based upon ARFD1100.dat (see below) and measure accessibility to all areas including the external area using a weight of the relative economic importance.

8.3 Area capacity

8.3.1 The area capacity file ARCP1100.dat is an indicator of the capacity of each Area and sector. In this application of DELTA it is derived from the total employment within each Area (and sector) and uses the AVZN1100.dat file (employment and household activity data) that was described in Chapter 2.

8.4 Area space costs

8.4.1 The Area space costs file ARCS1100.dat provides area-level information on the space costs for each sector. This is based upon the floorspace per worker and the rent. Base-year data is derived from the AVZN1100.dat and SPZN1100.dat (base year floorspace database). The base year data bases have been described in Chapter 2.

8.5 Area environment database file

8.5.1 The area environmental database file, AREN1100.dat file is used in the migration model. It is designed to encompass factors which might influence people's desire to migrate.

8.5.2 Within TELMoS12 it is based on population density by area. The assumption that is applied within the Migration Model (and described in Chapter 15) is that areas with high population density, such as city centre zones, will attract young households, whilst larger households (including families) will be attracted to suburbs and more rural areas

8.6 Area economy

8.6.1 The ARFD1100.dat file provides a measure of the economy within each area (and hence its economic importance). This data file contains information on government expenditure and exports. It is described fully in Chapter 9 and the description of the Economic Scenario.

8.7 Migration model distances database file

8.7.1 The migration model distances file, MMDS1100.dat describes the distances between areas and is used by the migration model. The data in this file remains unchanged from TELMoS07.

8.8 Generalised costs database files

8.8.1 The ARMX1100.dat and ARMC1100.dat files contain area-level generalised costs derived from the Generalised Costs generated by the Transport Demand Model.

8.8.2 The base year data is based upon the 2012 generalised costs.

9 SCENARIO INPUTS

9.1 Introduction

9.1.1 This section describes the implementation of the demographic and economic scenarios within the TELMoS12 land use model base case.

9.1.2 The Demographic scenario is based on the 2010 General Register of Scotland (GROS) employment forecasts.

9.1.3 The Economic Scenario is based on economic growth rates from forecasts prepared by the Centre for Economic and Business Research (CEBR). The CEBR forecasts only provide forecasts for total employment. Sector-level employment trends are derived from Ernst and Young Scottish ITEM 2013 forecasts of GVA and Employment.

9.2 The application of scenarios within DELTA

9.2.1 The scenarios are one of the key inputs within DELTA. They constrain the overall level of growth in population, households and employment over the forecast period.

9.2.2 The approach that has been taken in the TELMoS12 land use model is consistent with that of TELMoS07. This involves constraining both the employment and population scenario at Modelled Area Level.

9.2.3 This means that transport and land use policies do not affect either the total size of the population or the economy within Scotland.

9.2.4 However the theoretical basis underpinning the DELTA model, whereby households and population move in response to changing employment opportunities is not compromised. In this case if the employment within an area grows or declines at a faster level then elsewhere, then we would expect the population (and specifically adults of working age) to respond to the change and move to (or in the case of employment decline, away from) the area.

9.3 The demographic scenario

9.3.1 The calibration of the TELMoS12 land use model demographic scenario involved the following steps:

- creation of a set of targets for the number of households by household type for the period to 2037 that are consistent with 2010 GROS forecasts
- creation of a set of population targets, by person type for the period to 2037 that are consistent with 2010 GROS forecatsts
- the generation of coefficients for input to the household formation, transition and distribution model that will produce numbers of households consistent with the household targets described above
- some adjustments to the coefficients that determine household size in order to allow for changing household size over the forecast period and ensure that the person targets are met

Creating the targets by household type

9.3.2 The 2010 GROS datasets contain forecasts of households and population for 5 year intervals for the period to 2035. The key data sets used are:

- Table 9-1 which provides forecasts by both age groups and the 3 person types children, working-aged adults, retired
- Table 3 which provides forecasts by broad household type (see Table 9-2).

Table 9-1 Projected population of Scotland (2010-based), by age group: ('000s)

Category	2010 base	2015	2020	2025	2030	2035
All Ages	**5,222**	**5,365**	**5,486**	**5,596**	**5,686**	**5,755**
0-15	912	922	959	968	959	941
16-29	975	979	920	895	910	944
30-44	1,036	1,017	1,067	1,125	1,107	1,051
45-59	1,092	1,149	1,117	1,035	1,014	1,064
60-74	801	851	925	983	1,040	1,017
75+	406	447	499	589	656	738
Children	912	922	959	968	959	941
Working ages	3,268	3,383	3,452	3,483	3,478	3,499
Pensionable ages	1,042	1,060	1,075	1,145	1,249	1,315

Table 9-2 GROS household projections for Scotland – (2010 based)

Household size	Household type	2010	2015	2020	2025	2030	2035
One person households	**1 adult male**	382,920	430,720	477,990	520,190	559,280	600,040
	1 adult female	479,650	522,300	565,460	605,620	645,770	687,950
Two person households	**2 adults**	719,150	767,560	812,490	844,090	865,020	883,800
	1 adult, 1 child	97,050	109,220	120,360	131,690	143,410	154,430
3+ person households	**1 adult, 2+ children**	68,710	73,930	80,910	87,860	92,430	95,040
	2+ adult 1+ children	420,190	388,670	363,420	347,730	337,730	323,930
	3+ person all adult	189,750	181,060	167,960	154,230	146,850	143,030
All households		2,357,420	2,473,460	2,588,600	2,691,410	2,790,490	2,888,230

9.3.3 Growth rates based upon this subset were calculated. These growth rates were then applied to the TELMoS land use model's 2011 Census based household and population database to create a projection from 2011 to 2037. This projection represents the target for change in total households and population over the forecast period.

9.3.4 The household data in Table 9-2 was re-assembled into 5 main household types that correlated with aggregations of the ten TELMoS household groups. They were subsequently disaggregated to the TELMoS groups using the relative proportions from TELMoS07. Table 9-3 shows the GROS households groups and the corresponding TELMoS household groups.

Table 9-3 Household activities - GROS against TELMoS

2010 GROS households	TELMoS12 household groups
Single Person Households	Young Single
	Older Single
	Retired Single
Lone Person Households	Single Parent
Two Adults no Children	Young Couple
	Older Couple
	Retired Couple
Three Adults no Children	3+ Adults
Two Adults with Children/Three Adults	Couple with children
	3+ Adults with Children

9.3.5 The household targets, by household type, are shown graphically in Figure 9-1. The target assumes a 23% increase in the number of households across the Modelled Area forecast in the period from 2011 to 2037. The largest increases, by individual household type, are amongst the numbers of retired couples (75%), retired singles (71%) single parents (49%) and young singles (49%). Declines are forecast in the numbers of 'couple with children' households (-15%), and households with 'three or more adults' plus children (- 51%).

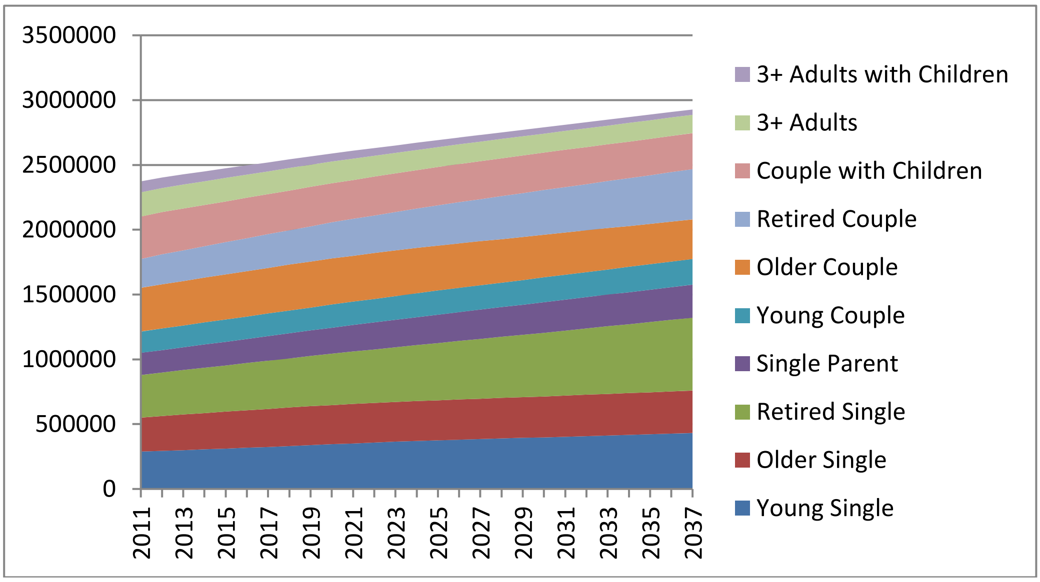


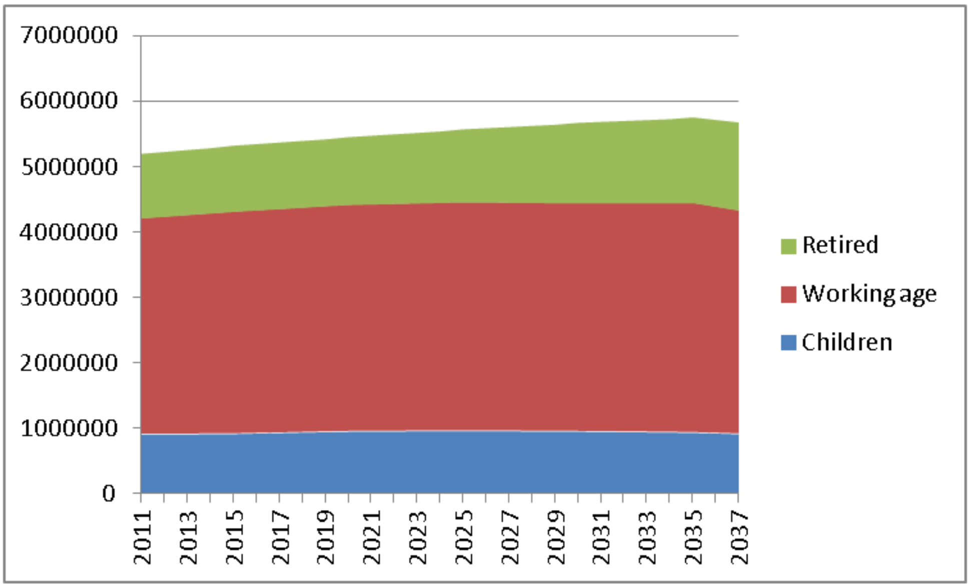
Figure 9-1 Household targets by the ten TELMoS land use model household types

Creating Population Targets by Person Type

9.3.6 The 2010 GROS forecasts for children, adults and retired were used to create the target for population change. Again growth rates were calculated for each individual person type. These were applied to the TELMoS land use model's 2011 Census based population data. A small adjustment was made to the retired population in order to exclude estimated retired persons not in households from the total retired population.

9.3.7 Figure 9-2 shows the person type targets (children, working age and retired). The target assumes a 9.2% increase in population over the period to 2037. The number of retired persons is forecast to increase by 36% whilst the numbers of children and working aged adults are forecast to increase by 0.7% and 3.5% respectively.

Figure 9-2 TELMoS land use model Population Targets by Person Type



Setting up the Initial Coefficient Values (including migration assumptions)

9.3.8 The numbers of households in the model are calculated each year by the household transition model. This process starts with the database of households at the start of the time period (ie the year), applies transition, dissolution, migsration and formation rates and calculates a new database of households for the end of the time period.

9.3.9 It is configured so as to be consistent with demographic scenario in terms of the numbers of households being formed or changing from one type to another (eg young couples becoming couples with children, or older couples becoming retired couples). The inputs to the household transition model define the rate of change of household formation, transition, dissolution and migration for different household types. In constraining the TELMoS land use model to be consistent with the target described in the previous section (and based upon externally generated forecasts) we need to adjust the coefficients associated with these processes to generate the correct numbers of households by type.

9.3.10 The starting values of the coefficients for generating demographic change (household formation, transformation and dissolution) were based upon a microsimulation model run of household change previously undertaken by DSC. These initial values have been adjusted for each forecast year using an optimizing process (described below) in order to create a set of coefficients whose outputs provide a match to the household targets.

9.3.11 It has been assumed that all the household groups will be allowed to migrate (in or out of the modelled area). The rates for migration (described as arrival and departure rates within the model) have been set at a lower level for retired persons reflecting observed data on the propensity to migrate.

Optimizing Process

9.3.12 The optimizing process is applied to each one-year period of the forecast **in turn**. It starts from the base year and optimises the household coefficients so that the forecast growth in households, by type is consistent with the target for the next twelve months. The process is then repeated for each year through to 2037.

9.3.13 In calculating the optimum model coefficients for each period, an iterative procedure is followed that calculates the changes in numbers of households and compares this to the target values (based upon 2010 GROS growth rates). The optimising process seeks to minimise the difference between the number of households forecast and the target values.

9.3.14 When optimising we set a tolerance for the difference between forecastand target. In this exercise, projections were calibrated at a tolerance of 0.01% of the total household target. Note that because we sum the **absolute** values of the errors, over-forecasting one household category and under-forecasting another does **not** cancel out.

9.3.15 We then set up a process which allows some of the coefficient values to be adjusted, with the adjusted values feeding into the household forecasting calculations. The adjustment process is multiplicative, so that coefficients whose initial values are zero will always remain zero. An adjustment value of 1 means no change from the initial value.

9.3.16 Around this we set up a single measure of the amount of adjustment made to the set of coefficients. In creating the TELMoS land use model's demographic scenario inputs this measure of adjustment is the sum of the squares of the changes made i**n** **e**ach of the transition, formation, dissolution and migration coefficients.

9.3.17 We then use the Excel Solver add-in to adjust the coefficients just enough to bring the forecast households to within the tolerated margin around the targets. Formally, this is an optimization process in which the objective function is to minimize the measure of total adjustment, subject to the constraints that:

- all the coefficients must remain greater than zero
- the error compared to the household targets must be less than or equal to the tolerance

9.3.18 Having run this for one year, the output numbers of households (rather than the target numbers) are used as the starting numbers of households for the next one-year step. That step in turn will be adjusted to match the targets for the end of that year. This procedure means that each year's adjustment process will try to correct the residual error in the results from the previous year; this prevents any tendency for errors to accumulate over the years.

Adjusting Coefficients for Person Types

9.3.19 The person types modelled in the TELMoS land use model are children, working adults and retired persons. The working age comprise the workers and non workers. The sum of all the person types constitutes the total population.

9.3.20 The coefficients used in simulating the growth or decline of persons over the forecast period, are initially based on the proportions of working age, children and retired people for each household activity group in the base year data.

9.3.21 These proportions are applied to forecast households derived from the optimising process described above. The resulting person-type forecasts may not match the person type targets at this stage. The proportions/coefficients are therefore adjusted to vary each year so as to enable the forecast person types to match the 2010 GROS forecasts for the model area whilst at the same time maintaining the household activity group forecasts.

9.3.22 These adjustments to the size of households were necessary to ensure that the households resulting from the calibration produced the correct number of persons. The coefficients whose adjustment is described here will be part of the inputs in the employment model ME12 files. They are also used in setting the right limits for the working and non working adults in the model.

9.3.23 The changes in numbers of non-working, non-retired adults calculated within the employment submodel (program ME12), after the demographic, migration and location processes, result entirely from adults gaining or losing jobs - if the number of residents in work increases, the number of non-working, non-retired adults must reduce to maintain the correct total population of that household type in the zone. The numbers of children and retired persons, in contrast, have nothing to do with employment status, but are calculated within the ME12 program simply because this is the one program in the DELTA model sequence which deals with persons rather than with households.

Outputs of the Demographic Scenario Calibration

9.3.24 The outputs of the optimization process are the demographic scenario coefficients. These are inputs to the transition model MT12 (see Chapter 14).

9.3.25 Figures 9-3 to 9-8 compare the source forecasts with the output from the TELMoS12 do-minimum forecast. The TELMoS output is based on the coefficients from the optimisation process described above. The forecasts show:

- a comparison of the forecast number of households in the GROS 2010-based forecasts and TELMoS Do-Minimum (Figure 9-3)
- a comparison of the forecast resident-based population in the GROS 2010-based forecasts and TELMoS Do-Minimum (Figure 9-4)
- a comparison of the forecast total population in the GROS 2010-based forecasts and TELMoS Do-Minimum (Figure 9-5)
- a comparison of the forecast number of children in the GROS 2010-based forecasts and TELMoS Do-Minimum (Figure 9-6)
- a comparison of the forecast number of working-age adults in the GROS 2010-based forecasts and TELMoS Do-Minimum (Figure 9-7)
- a comparison of the forecast number of retired persons in the GROS 2010-based forecasts and TELMoS Do-Minimum (Figure 9-8)

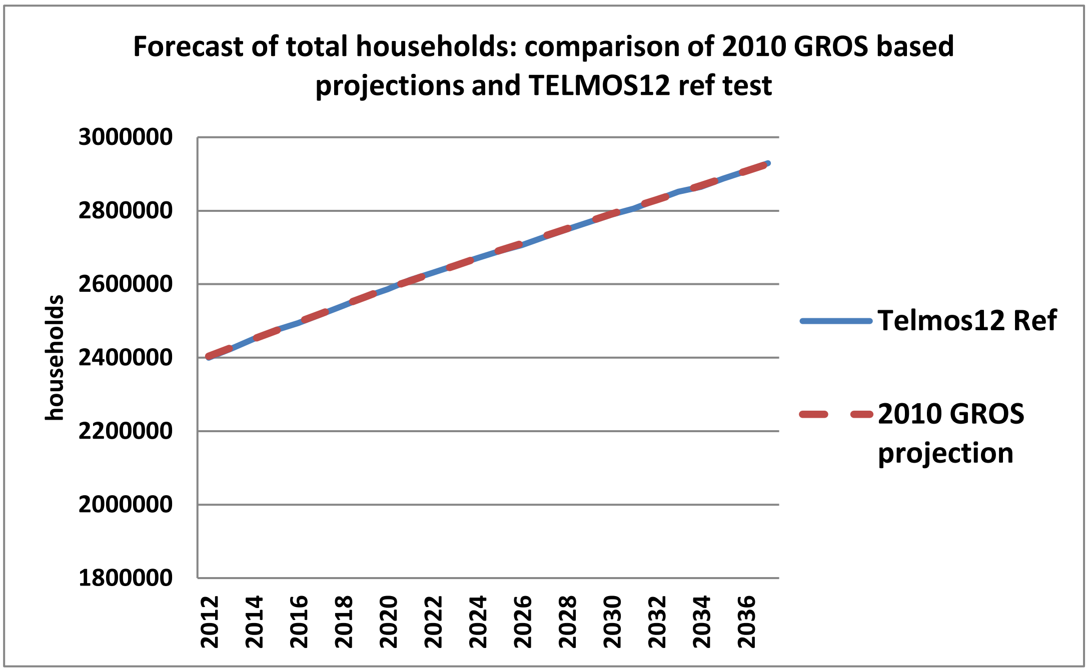


Figure 9-3 TELMoS12 household forecast and 2010 GROS projections

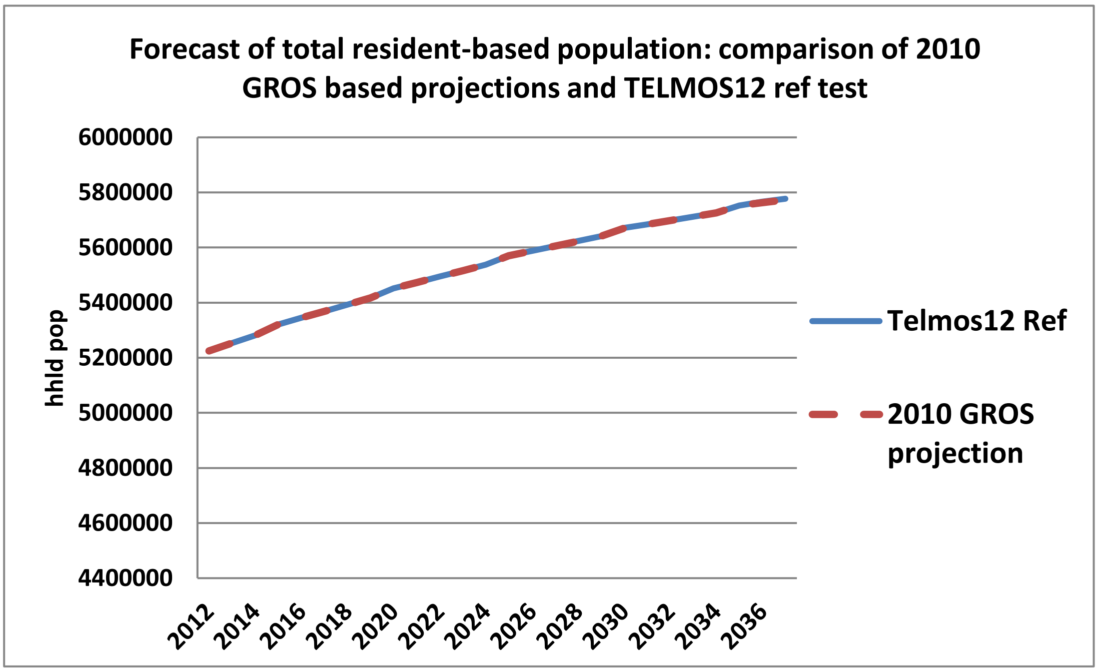


Figure 9-4 TELMoS12 resident-based Population forecast and 2010 GROS projections

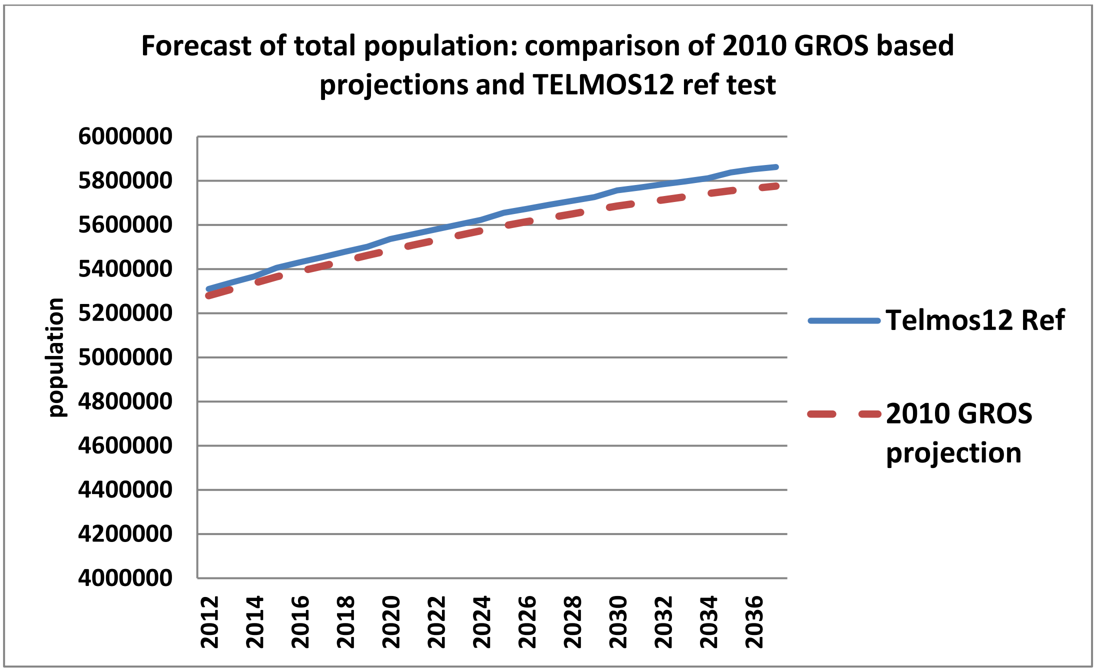


Figure 9-5 TELMoS12 Total Population forecast and 2010 GROS projections

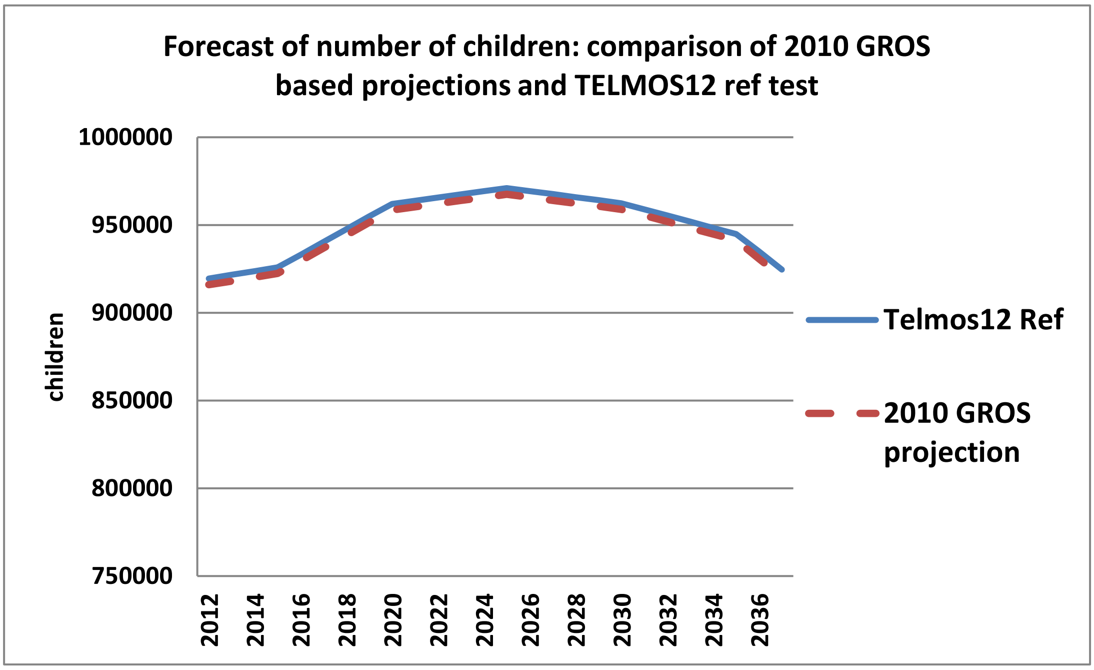


Figure 9-6 TELMoS12 children forecast and 2010 GROS projections

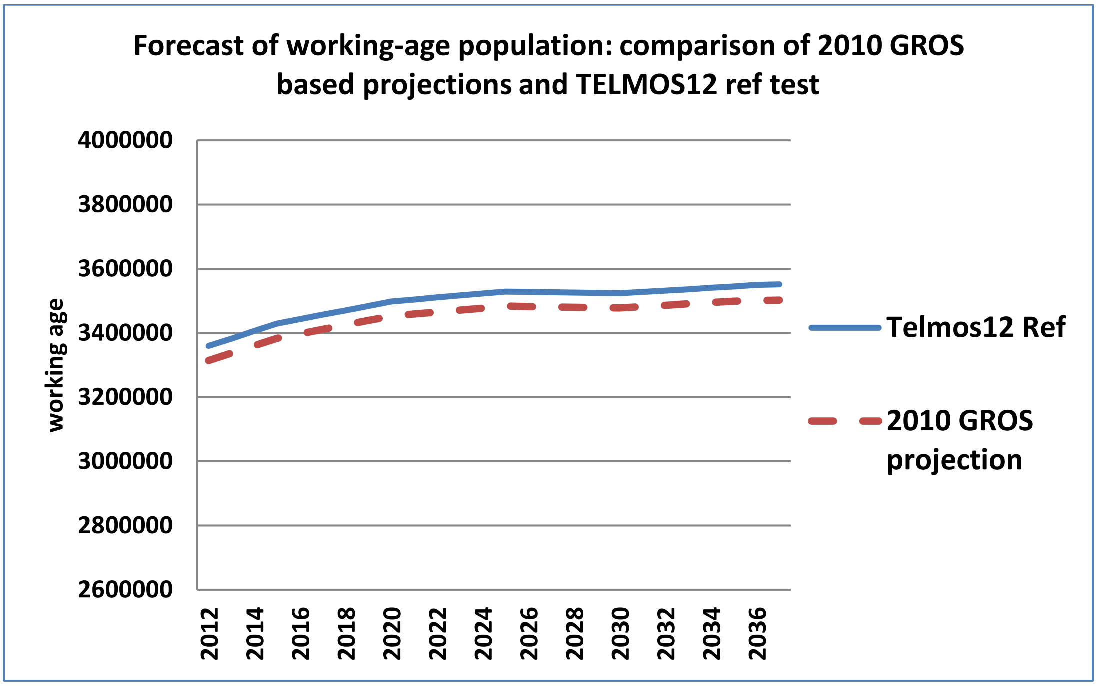


Figure 9-7 TELMoS12 working age forecast and 2010 GROS projections

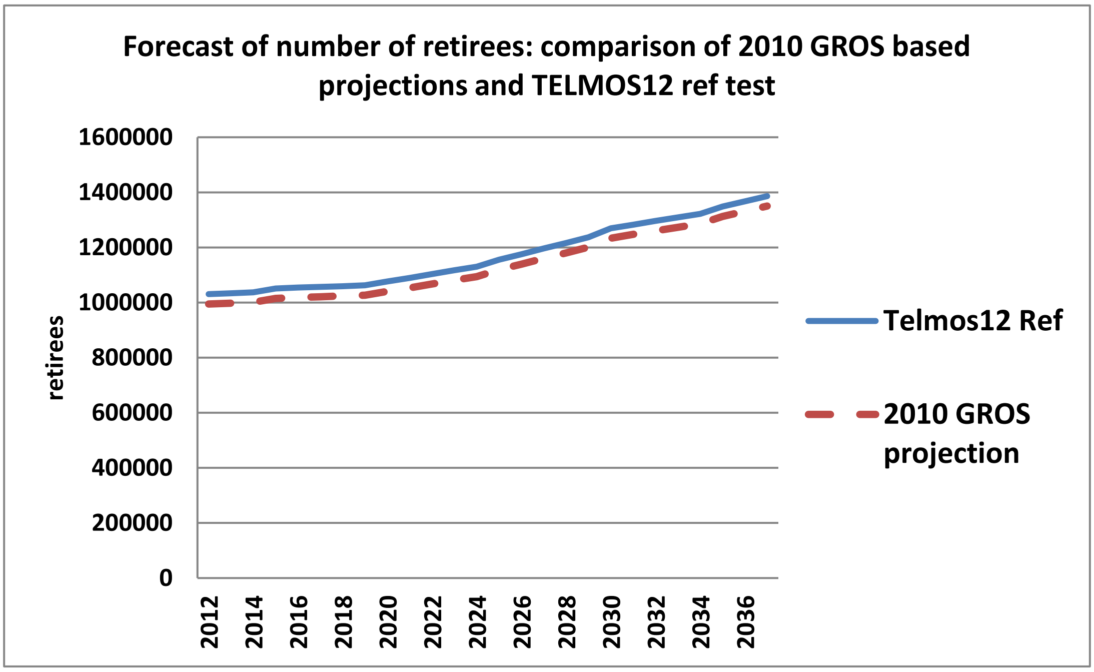


Figure 9-8 TELMoS12 retired people forecast and 2010 GROS projections

9.4 The economic scenario

9.4.1 Like the inputs to the urban level of DELTA, the inputs to the regional model are a mixture of scenario and behavioural coefficients. The coefficients include parameters derived from the GVA and employment targets for the Economic scenario.

9.4.2 This section describes the REM and the Economic Scenario. The REM is run in conjunction with the Urban model and there is a feedback of inputs from across both models. In TELMoS12 the full REM is run from the year 2012 to 2037. However, an initial REM run was performed from 2009 to 2011. This is used to generate a 2011 and subsequently a 2012 REM database based on the 2009 REM database derived from the published Industry by Industry Input-output tables referred to in Chapter 7. There are two important distinctions between the REM for 2009-2011 and the REM for 2012 onwards, namely:

- the REM is run as a stand-alone model for 2009-2011 rather than being linked to the urban model
- only the production and trade model programs (PX12, MP12, PC12 and AA12) are run for the 2009-2011 period. The investment model is not run.

9.4.3 Running these programs in this way implies that the link from the urban model to the REM exists but there is no link, in the opposite direction, from the REM to the urban model. This enables us to use the observed changes in employment as estimates of the changes in capacity whilst at the same time not over complicating the running of the constrained to observe data urban model by trying to impose REM outputs on it. As the 2011 and 2012 urban model was calculated separately and based upon external sources of data for 2011 (or 2012), as described previously in this report, there was no requirement to have feedback from the REM to the urban model.

9.5 Creating the 2012 base year database

9.5.1 The 2012 base has been created by running the DELTA programms (that are modelled within each year) using the 2011-based data. This produces a set of 2012 datafiles (as output). These have then formed the 2012 base year for TELMoS2012.

9.6 Creating the 2009-2011 REM

9.6.1 The output of the trade and production (MP12) for 2009 is calibrated so as to reproduce the Industry by Industry Input-output table referred to in Chapter 6. This serves as a check to establish the REM has been set up well in the 2009 Empirical year.

9.6.2 In order to create the 2012 REM database the production and trade model have been run in the empirical data year 2009 and through to 2012 which is the TELMoS12 base year.

9.6.3 The final demands by sector for Government expenditure, household consumer demand and Exports have been estimated for 2010 and 2011 based on the measured GVA growth taken from Scottish Government published statistics.

9.6.4 PX12 program calculates consumer final demand by sector and area using information on consumer demand by sector that is estimated to grow in line with GVA.

9.6.5 MP12 program calculates the pattern of trade and volumes of production by area, based upon the estimated final demand which is input exogenously.

9.6.6 Table 9-4 shows the Production, Value Added, Government Expenditure and Exports for the Empirical data year 2009 and TELMoS12 base year 2012.

Table 9-4 REM output for 2009 and 2012 (£ million)

Sector	2009	2012
Gross Value Added	106,782	109,445
Total Production	210,920	216,355
Government Expenditure	47,888	49,049
Consumer Demand	47,231	48,379
Exports	52,194	49,049

9.6.7 The Input-Output coefficients taken from tables for the published 2009 Domestic Flows is shown in Table 9-5.

Table 9-5 The REM input-output coeffients

Economic Sectors	Agricultu re,	Mining & quarrying	Manufact uring	Electricity , gas &	Construct ion	Distributi on &	Transport &	Finance & business	Public administr ation &	Other services
Agriculture, forestry & fishing	0.1345	0.0003	0.0287	0.0008	0.0008	0.0036	0.0003	0.0001	0.0002	0.0003
Mining & quarrying	0.0011	0.0376	0.0099	0.0145	0.0086	0.0016	0.0008	0.0007	0.0007	0.0006
Manufacturing	0.1072	0.0455	0.1630	0.0340	0.0894	0.0526	0.0441	0.0065	0.0341	0.0233
Electricity, gas & water supply	0.0212	0.0395	0.0150	0.3334	0.0038	0.0078	0.0050	0.0033	0.0112	0.0115
Construction	0.0082	0.0628	0.0036	0.0115	0.2296	0.0160	0.0123	0.0226	0.0081	0.0102
Distribution & hotels	0.0487	0.0119	0.0380	0.0150	0.0200	0.0233	0.0129	0.0063	0.0182	0.0093
Transport & communication	0.0307	0.0405	0.0171	0.0091	0.0123	0.0870	0.1420	0.0341	0.0241	0.0241
Finance & business services	0.0541	0.0546	0.0194	0.0153	0.0393	0.0600	0.0370	0.1537	0.0415	0.0421
Public administration & defence, Education & Health	0.0044	0.0318	0.0119	0.0112	0.0272	0.0186	0.0391	0.0459	0.0904	0.0532
Other services	0.0033	0.0071	0.0013	0.0025	0.0009	0.0032	0.0071	0.0035	0.0068	0.0715

9.7 <u>Creating 2012 to 2037 REM</u>

9.7.1 TELMoS12 economic scenario is constrained to CEBR forecasts provided by Transport Scotland (see Chapter 6). In particular, the scenario applies the CEBR annual growth rates for GVA and Employment.

9.7.2 The CEBR forecasts run to 2026. Transport Scotland have advised that an economic scenario that assumes an annual 1.5% growth in GVA and no change in employment beyond 2026 should be applied.

9.7.3 GVA and Employment figures by Sector from Ernst and Young Scottish ITEM Club 2013 Forecasts has been used to calibrate GVA and Employment growth by the ten TELMoS sectors in the Economic Scenario. The data is for the period to 2016 and assumptions of the relative distribution of the sectors and the trends beyond 2016 have been inherited from the older version of the Ernst and Young forecasts used in TELMoS:07 model.

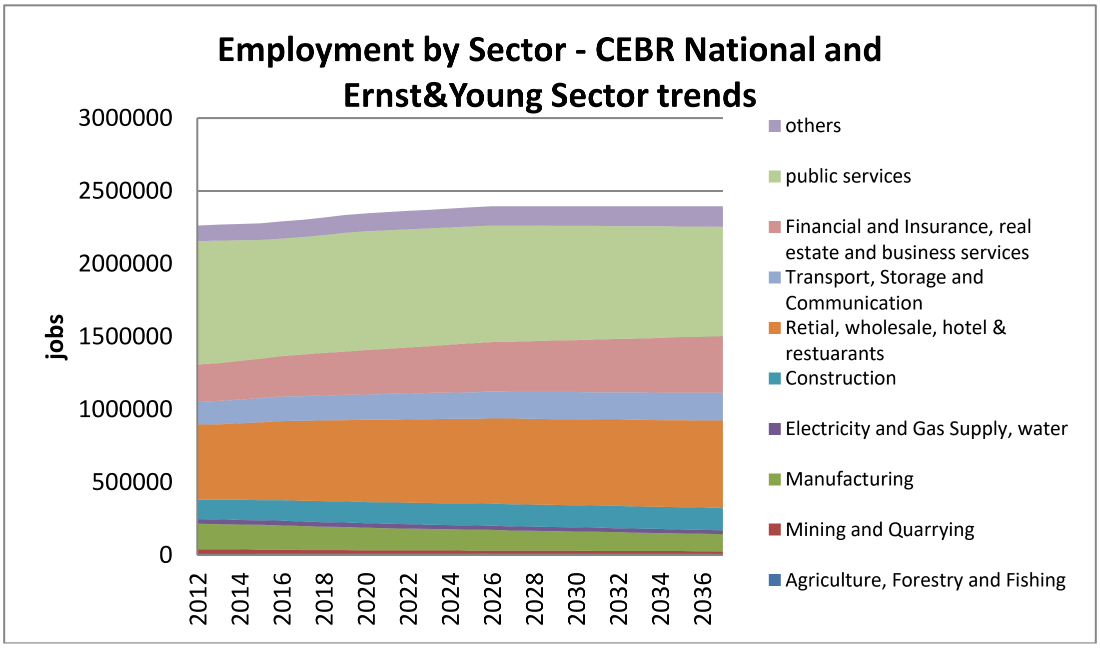
9.7.4 The components of the REM for the period to 2037 are summaried in Table 9-6.

Table 9-6 TELMoS:12 Regional Economic Scenario – Targets (£ million)

Sector	2012	2017	2022	2027	2032	2037
Gross Value Added	109,143	115,451	124,497	134,388	144,774	155,963
Total Production	216,355	228,859	246,790	266,398	286,986	309,166
Government Expenditure	49,049	49,521	51,808	54,408	57,343	60,732
Consumer Demand	48,379	52,350	57,508	62,948	68,516	74,390
Exports	49,049	57,842	62,903	68,545	74,408	80,654

9.7.5 Figure 9-9 shows the target figures for employment by sector for the period to 2037 that are based upon the CEBR and Ernst and Young Scottish ITEM club forecasts.

Figure 9-9 the employment by sector trends for the targets used in setting up the TELMoS12 economic scenario



9.7.6 The main components of the overall economic scenario which are input into the regional economic model are:

- the annual totals of non-consumer final demand
- the technical coefficients of the input-output model in Table 9-5 above
- the productivity assumptions in the production and capacity models

9.7.7 Other components of the economic scenario include:

- development costs per unit floorspace, for the Fully Modelled Area in general and (optionally) by zone (in the development model – see Chapter 13)

9.7.8 The following trade and production model inputs are used in TELMoS12:

- consumer demand by sector growing in line with GVA
- value-added per unit of production by sector
- sensitivities of trade to cost
- input-output coefficients (including demand for imports)
- expected employment per unit production
- scaling factors for space costs

<u>Consumer final demand</u>

9.7.9 Figures for Consumer final demand are exogenously input into the MP12 input file. Their calculation is based on the 2009 consumer demand from the Industry by Industry domestic flow table described in Chapter 6. The GVA growth forecasts are applied to 2009 Final demand to generate demand in the future years. This is based on the assumption that household consumption is based on household incomes which are also affected linearly by GVA growth.

<u>Value-added per unit of production</u>

9.7.10 These values are input into MPIN01 and were derived from Industry by Industry Input-Output table for 2009. The coefficients, for each sector, are equal to the ratio of that sectors gross value added at basic prices to that sectors output at basic prices.

<u>Sensitivities of trade to cost, and accessibility constants</u>

9.7.11 The coefficients that reflect the sensitivities of trade to cost and accessibility are the result of direct calibration of the DELTA model itself. Trade distances have been calibrated by adjusting the cost parameter coefficients in the MP12 input file. Table 9-7 shows both target and the model's trade distances. For some sectors the target trade distance was smaller than the intra-area distances contained in the MMDS file, where this was the case the trade distance in the model is slightly higher than desired. Target distances for goods movement were based on average lengths of haul estimated in previous Scottish projects. Those for services were based more on business trip distances.

Table 9-7 REM comparison of target distances and inter-area distances

REM Sector	Target Distance	Model Distance
101	74	74.5
102	45	44.9
103	78	79.5
104	45	44.4
105	30	29.6
106	13	15.1
107	30	29.9
108	25	24.6
109	11	15.1
110	11	14.9

Input-output coefficients

9.7.12 The input-output coefficients (defining the relationships between sectors within the Scottish economy) are kept constant over the period 2012 to 2037 and the growth in economy is therefore driven by growth in final demand. This coefficients are in Table 9-5 above.

Expected employment per unit production

9.7.13 The ratios of expected employment per unit production are input into MPINP5. These were estimated so as to reconcile the economic scenario in monetary terms with the employment scenario in terms of numbers of jobs. It is the total production related jobs by sector divided by the total production by sector.

Scaling factors for space costs

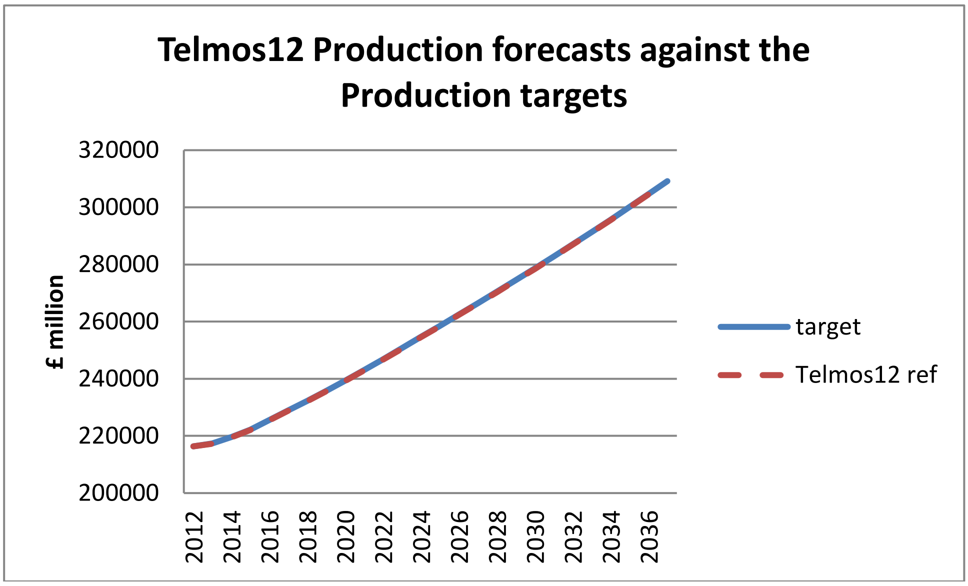
9.7.14 These are simple conversion factors to scale space costs from the units of rent (£/week) to the REM units (£M/year).

9.8 Economic Scenario Model Outputs

9.8.1 Figures 9-10 to 9-13 compare output from the TELMoS12 Do Minimum forecast with the source data used when creating the economic scenario.

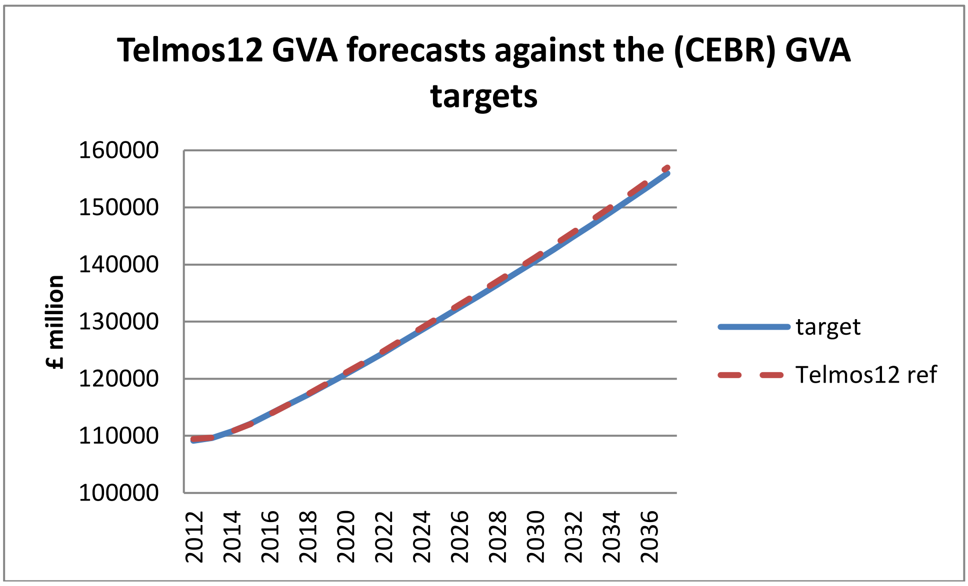
9.8.2 Figure 9-11 shows the Do-Minimum test forecast of production (for Scotland) with a calculation of the level of production based upon the CEBR economic forecasts of GVA.

Figure 9-10 Graph comparing the TELMO12 model production forecasts against the Production targets



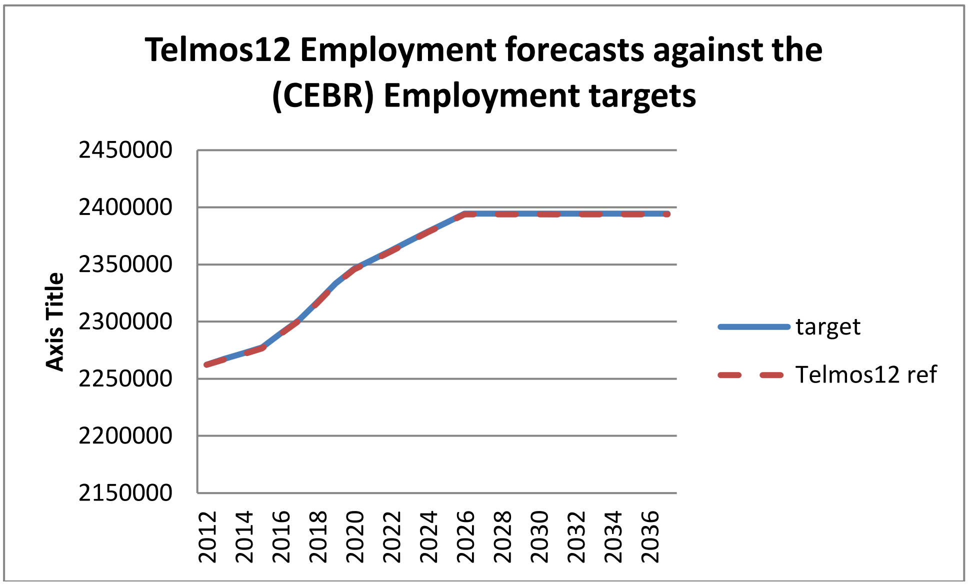
9.8.3 Figure 9-11 shows a comparison of GVA forecast in the Do-Minimum forecast and the CEBR-based forecast.

Figure 9-11 Comparison of TELMoS12 Do-minimum forecast GVA and CEBR-based targets



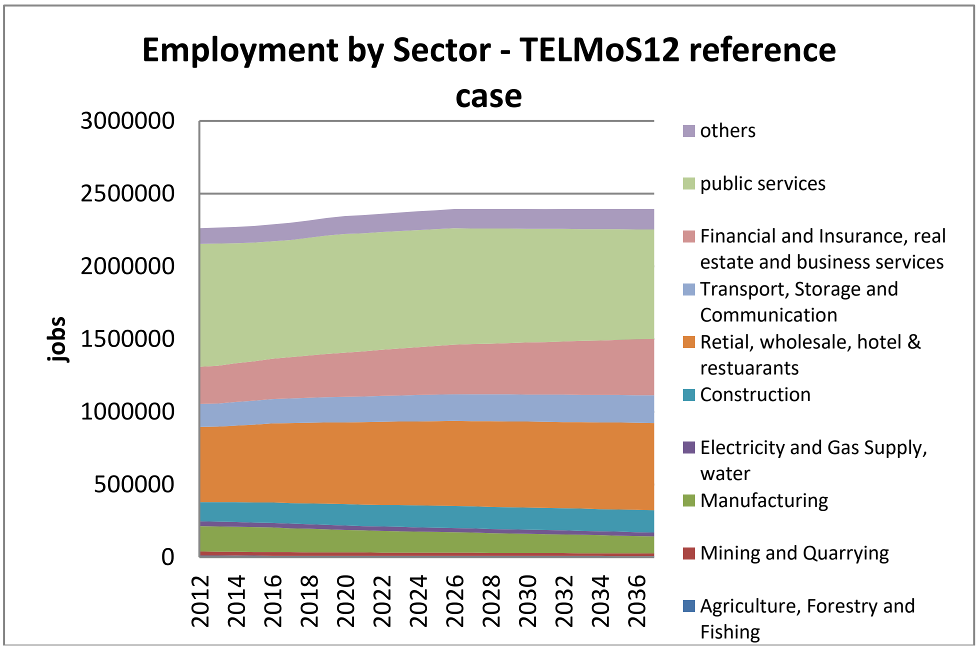
9.8.4 Figure 9-12 shows a comparison of the national employment forecast of the Do-Minimum forecast and the CEBR-based forecast. The latter includes the assumption of zero growth in employment post 2026.

Figure 9-12 Comparison of TELMoS12 Do Minimum total employment forecast and the CEBR-based employment targets



9.8.5 Figure 9-13 shows the Do-Miniumum forecast for employment, disaggregated by sector. This sectoral split is based upon the Ernst and Young forecasts to 2016 and an extrapolation of that source thereafter.

Figure 9-13 TELMoS Do-minimum forecast – sectoral employment change 2012-2037



10 POLICY INPUTS

10.1 Overview

10.1.1 Information on the future scale and distribution of permissible development forms one of the three key inputs to TELMoS. It influences or controls the model's forecasts of future floorspace, and hence can strongly influence where people live and work. It determines:

- where development may take place
- in which year land for development is likely to come forward
- the maximum amount of development that may take place in any zone

10.1.2 This information has been collected by Transport Scotland at two-yearly intervals since the TELMoS model was first commissioned. On each occasion the request has been for information on:

- committed development, including those sites with planning permission and allocations
- other sites that are expected to come forward and be available for development over the course of the forecast period

10.1.3 The results of the most recent exercise to collect planning inputs are reported in a separate report[6].

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[6] DSC Project Note 7 "TELMoS12 : Assembly of Planning Policy Inputs (APPI2012)"

11 MODEL COMPONENTS AND CALIBRATION: OVERVIEW

11.1 Introduction

11.1.1 This chapter provides a general description of the model components. It also provides a similar overview of the ways in which the components of the model have been calibrated.

11.1.2 The remaining chapters of this report provide further detail on the components and their calibration, and necessarily repeat much of what is written in this chapter.

11.1.3 The model components are described in sequence starting immediately after the transport model (i.e. below the orange bar in Table 2-1) and continuing through the following year.

11.2 The model components

11.2.1 The **accessibility** component takes the most recent generalised costs supplied by the transport model TMfS12 and the most current pattern of land-uses and calculates measures of accessibility for each activity. These measure how difficult it is (in generalised cost units) for households to reach the range of destinations they are likely to require, or for businesses to be reached by the range of people and firms (workers, suppliers, clients) who are likely to need to reach them.

11.2.2 The **environment** component serves the very specific purpose of providing a measure of the environmental impact of transport for use in the residential location model. Numerous other environmental outputs can be obtained from the transport model itself, and are documented elsewhere. The environmental measure used is the density of traffic in each zone, converted into an index for use in the location model.

11.2.3 The accessibility and environment components are run at the end of the sequence for any one year, after the transport model (if the year is a transport model year). These are also the only components of the model proper which run in the base year. It is important to note that they need to be rerun (and various related adjustments made) if the base year transport model is revised in any way that affects generalised costs or traffic volumes.

11.2.4 We now move to the next year, and hence back to the top of Table 2-1.

11.2.5 The **development** component forecasts changes in the quantities of floorspace available to activities. The three main components of change are demolition (specified by the model user), exogenous developments (developments which will definitely happen or are input for the purpose of what-if tests, again specified by the user), and permissible development - development forecast by the model as occurring in response to the economic conditions, within the limits of the input planning policy measures. For permissible development, there is a timelag from the year in which the model forecasts that the development will be undertaken to the year in which the resulting floorspace becomes available to locating activities. Exogenous development is input in the year that it becomes available for use.

11.2.6 The **production**, **trade and investment** components are used in the TELMoS12 land use model to implement the economic scenario. The economic scenario has been calibrated such that the overall Employment at the Scottish National level grows in line with the CEBR forecasts whiles the sector grows in line with Ernst & Young forecasts as described in detail in section 5.4.

11.2.7 The outputs of the production, trade and inverstment components are forecasts of investment by Area, the patterns of trade and volumes of production by area, and consumer final demand. The trade between areas is converted into physical flows (within the **Freight Model**). These outputs inform the calculation of demand for and location of employment within the Urban Model.

11.2.8 The **household transition** component represents the processes by which the number and mix of household types change over each time period (i.e. each year). These changes are made by a combination of transition of households from one type to another (i.e. a single young adult becoming a single older adult), the dissolution of households (for example where two single households becomes one couple households and there is one less household), and household formation (for example where a grown up child leaves the family home to form a new household).

11.2.9 The outputs from the household transition component are:

- the numbers of surviving households by type in each zone (ie households which have not dissolved or migrated away), split between mobile and immobile households
- the number of pool households by area

11.2.10 At this point the pool households are just the newly-formed households. Migrant households are added (and subtracted), by the **migration** component, which forecasts longer-distance household moves. It operates at the area level, rather than at the zone level. ‘Push’ and ‘Pull’ factors are calculated for each area based upon:

- the proportion of adults in work
- life-style factors
- rents

11.2.11 The outputs of this model – the movement of households from one area to another are an input to the household location model. There the households are included along with the other mobile and pool households and assigned to zones. The migration component also deals with households migrating out of or into the Modelled Area. The rates of migration are fixed in the model but may vary for year in a way that the model reproduces the 2010 GROS scenario for the Modelled Area as a whole.

11.2.12 The **income** component calculates expected incomes based on household type and the previous number of workers per household, for each household type in each zone. The incomes calculated are estimates of net household incomes after tax, National Insurance and money benefits. They remain unchanged from TELMoS07. They are reported in constant 2001 prices.

11.2.13 The **car ownership** component forecasts the proportions of households of each type, in each zone, which will own a car or cars. Growth in real incomes is usually the main driver of growth in car ownership, but other variables are also taken into account; in a no-growth situation, growth in car ownership may stop or decline.

11.2.14 Car ownership is forecast conditional upon location, ie it is a forecast of the proportion of households of a particular type that will own a car or cars **if** they locate in a particular zone. These proportions are used to weight the accessibility measures for the effects of car ownership, before their use in the household location calculations.

11.2.15 The **household location** component assigns mobile households to zones. The mobile households in any one year consist of

- "pool" or "must-move" households, ie newly formed households (from the Transition model) and long distance migrating households (from the Migration model)
- "may-move" households, who are already living in a specific zone, but may move

11.2.16 Note that these categories are, overall, a minority of households; in any one year and in most zones, the majority of households are immobile, and their housing is excluded from the housing market represented in the location component.

11.2.17 The key influences on location choice are availability of housing, cost of location, accessibility, housing quality, and environment. The cost of location is determined mainly by the rent in each zone, which the household location component adjusts in order to balance supply and demand, up to a certain point: if demand is low, increasing proportions of housing will be left vacant. If demand is high, households are modelled as fitting themselves into the available housing by occupying less space; in reality, this would involve increasing levels of sharing or of "concealed households" (eg young adults obliged to continue living with their parents, because of the high cost of moving out relative to their incomes).

11.2.18 The household location component outputs the updated numbers of households of each type living in each zone, the amount of occupied floorspace, the amount of vacant floorspace and the rent levels for housing floorspace.

11.2.19 The **employment location** model is similar to the household location model. It assigns mobile employment (jobs) to zones, and forecasts the changes in the rent and occupancy of employment floorspace. The key influences on location choice are accessibility, availability of commercial floorspace and the cost of location. Separate location models operate for each commercial floorspace type.

11.2.20 The outputs from the location model will be the number of jobs within each zone by sector and floorspace type, the amount of occupied floorspace, the amount of vacant floorspace and the rent levels for floorspace (of each type).

11.2.21 The **employment status** component has three main functions (and takes its name from the second of these):

- firstly, it takes the jobs by sector calculated in the employment location model and converts these to jobs by socio-economic level
- secondly, it adjusts the labour supply by increasing the numbers of adults of working age in work (and reducing the numbers not in work) to match the labour demand, ie to match the number of jobs by socio-economic level
- thirdly it calculates the numbers of children and people in retirement within each zone

11.2.22 Within the first two of these steps, the model updates matrices of travel to work which are used within the land-use model to track the connections between workplaces and residences. Note that the employment **status** component concentrates on the working/non-working status of residents; it takes the number and location of jobs as given (from the earlier employment **location** component).

11.2.23 The outputs from the employment status model are the number of people by the four population groups modelled within DELTA (i.e. children, working-age adults in employment, working-age adults not in employment, retired), the number of jobs by socio-economic level and matrices of journey to work. These outputs provide most of the inputs from the TELMoS12 land use model to TMfS12.

11.2.24 The **housing quality** component is applied to the residential floorspace. It calculates changes in the area quality that result from other changes predicted by the model. As such it represents the effects that users of space can have on the characteristics of an area. The typical case is that the neglect of houses and their gardens by one group of residents may affect the attractiveness of the area to other residents and potential residents.

11.2.25 This completes the cycle: the next step is either to run the transport model (if this is a transport model year) and then to start again with the accessibility calculations, or – if this is not a transport model year – to go straight on to the accessibility calculations.

11.3 Characteristics of the model

11.3.1 It is worth noting some characteristics of the model which result from (or are reflected in) the above design.

11.3.2 First, most of the model components explicitly forecast one particular aspect of change over a one-year period. Only the accessibility and environmental calculations produce absolute values independent of previous values, and these components are essentially the preparation of inputs for use in the location model.

11.3.3 Secondly, it follows that after the first one-year period, most of the input data used by the model is supplied by the model itself. This is particularly true of the household location modelling, which is at the heart of DELTA, and which takes account of:

- accessibilities – using outputs from the transport model and a whole range of previous land-use model results
- environment – using outputs from the transport model (which in forecast years themselves depend on the land-use model results)
- floorspace quantity and quality - from the development and quality models, which are themselves influenced by previous land-use model outputs such as rents
- incomes – largely defined by the economic scenario, but modified by previous land-use changes
- rents – which are endogenous to the location model

11.3.4 The TELMoS land use model forecasts are therefore a process of cumulative causation – the outputs in any one year are the result of all the previous years – in which "everything affects everything else", or very nearly so. One practical consequence is that if we revise the inputs for any one year, we should for consistency rerun the model for all the subsequent years. However, the model is not generally chaotic in the mathematical sense – it is highly unlikely that a small change to base data or inputs in one year will have a dramatic effect on the overall results later on. There are considerable negative feedback loops in the overall model which tend to damp down change; there are also important positive feedback loops which can amplify changes, but the most important of these at the zonal level, the development sub-model, is usually constrained by restrictive planning policy inputs.

11.3.5 Because the model works forward through time, there is no definitive "final year" – forecasts are necessarily run to a specific year, but in modelling terms that is just another year in the sequence. Within this dynamic, the "actors" – households and household members, businesses and developers, are "myopic" in the sense that they respond to present or (more often) past conditions, but do not attempt explicitly to respond to future changes. The impacts of transport investments therefore do not start to appear until the scheme is "open" and affecting generalised costs. This is partly for practicality – it would probably be very time-consuming to operate a model in which actors could "foresee" transport change – and partly because the evidence of actors responding in advance of transport change is, at best, inconclusive.

11.3.6 A related point is that there is no overall iterative structure to the model – it is essential linear. There are two components in which iteration is used to find equilibrium solutions: the location model and the employment status model. In both cases the equilibrium found is a very partial, short-term one – especially in the location model, where a separate short-term equilibrium is found for each type of floorspace, and that only for the minority of floorspace which is in the market in any one year. The labour market equilibrium found in the employment status model is slightly more comprehensive, in that (in principle) any potential worker may change whether or where he or she works; this is done partly so that all the forecast jobs will be filled with workers, to ensure consistency with the forecast scenario.

11.4 Calibration of the model components

11.4.1 The absence of static modelling components means that it is neither necessary nor possible to carry out cross-sectional type of calibration to reproduce the base year situation, in the way which is familiar to most transport modellers and some land-use modellers. The intention of DELTA package has therefore always been that the values of the land-use model parameters should if possible be defined by reference to findings from work in urban economics, demography, housing economics, etc.; there is a large volume of such work which, until the early 1990s, was almost entirely ignored in land-use/transport modelling. The "ideal" calibration of a DELTA model would be drawn entirely from published, peer-reviewed results of previous work across a range of regions and circumstances. This last phrase relates to another element of the approach to calibration: even if it was possible to calibrate every coefficient used within TELMoS from recent Scottish regional data, we would still consider it to be preferable to draw on a wider range of evidence, in order that the model coefficients should not be biased by the particular conditions in Scotland in the last few years. In practice, it is not remotely possible to calibrate the entire model from recent local data, and the use of a wider range of material is a necessity.

11.4.2 The available material is extensive, but does not provide all the required parameters, mainly because the zonal level of models such as TELMoS is a finer level of analysis than most research, and because a lot of research in urban economics and related disciplines ignore transport and is therefore unhelpful to the central requirement that TELMoS (with TMfS) should be a model of land-use/transport interaction. However, DSC have made progress, over successive DELTA projects, by a mixture of:

- directly using coefficients or other values estimated by others

- adjusting sub-models to reproduce elasticities or similar ratios reported by others
- adjusting sub-models to reproduce elasticities or similar ratios implied by others' results
- use of professional judgement, where use of quantitative results is impossible, to to ensure that the results of the model are in accordance with the "stylised facts" typically found in the conclusions to research papers

11.4.3 The use of these different approaches is noted in the detailed reporting in later chapters, with references to the preceding work wherever appropriate.

11.4.4 The following paragraphs summarise the main approaches used in each component (this does not attempt to be comprehensive; the details are in the later chapters).

11.4.5 Accessibility calculations:

- sensitivity to generalised cost based on previous transport modelling work (and successful use of these sensitivities in previous projects)

11.4.6 Development model

- total development models calibrated so that at "normal" development costs, and when unconstrained by planning policy, floorspace supply will grow approximately in proportion to the growth in the occupying activities allocation of development to zones – professional judgement informed by observation of development patterns

11.4.7 Investment model:

- professional judgement informed by review of literature on patterns of economic growth (or decline)

11.4.8 Household transition model:

- initial coefficients derived from own household/population microsimulation modelling, itself based largely on registration statistics (births, marriages, deaths)
- adjusted so that the Do Minimum Model household results match the target scenario

11.4.9 Migration model:

- simplified and adapted version of a published national model, tested against a different published model

11.4.10 Income model:

- based on relative incomes in observed data, with some estimation to arrive at the full set of values by household composition, age and socio-economic level

11.4.11 Car ownership model:

- coefficients taken directly from DfT NATCOP model

11.4.12 Household and employment location:

- coefficients from a variety of sources, with a significant element of professional judgement, tested by comparing the effect of accessibility changes on property values against results from various empirical analyses

11.4.13 Employment status:

- conversion of employment from sector to socio-economic level based on 2001 Census data
- persons per household based on 2011 Census data, adjusted in line with the demographic scenario
- adjustment to allocate workers to jobs: this is an iterative factoring process without coefficients

11.4.14 Housing quality:

- professional judgement, informed by observation of changes in the quality of residential areas and by testing previous model applications

12 ACCESSIBILITY MODEL

12.1 Overview

12.1.1 The Accessibility sub-model takes the generalised costs that are generated by the transport model and calculates:

- accessibility for each measure (i.e. commuting, shopping, business trip etc)
- accessibility for each household and employment type.

12.1.2 The outputs from the model are:

- a set of origin accessibilities for household and employment activities
- a set of destination accessibilities for households and employment activities.

12.1.3 These accessibility measures are used in other sub-models and inform location decisions.

12.1.4 The formulae used within this model are shown in Appendix A.2.

12.2 Introduction

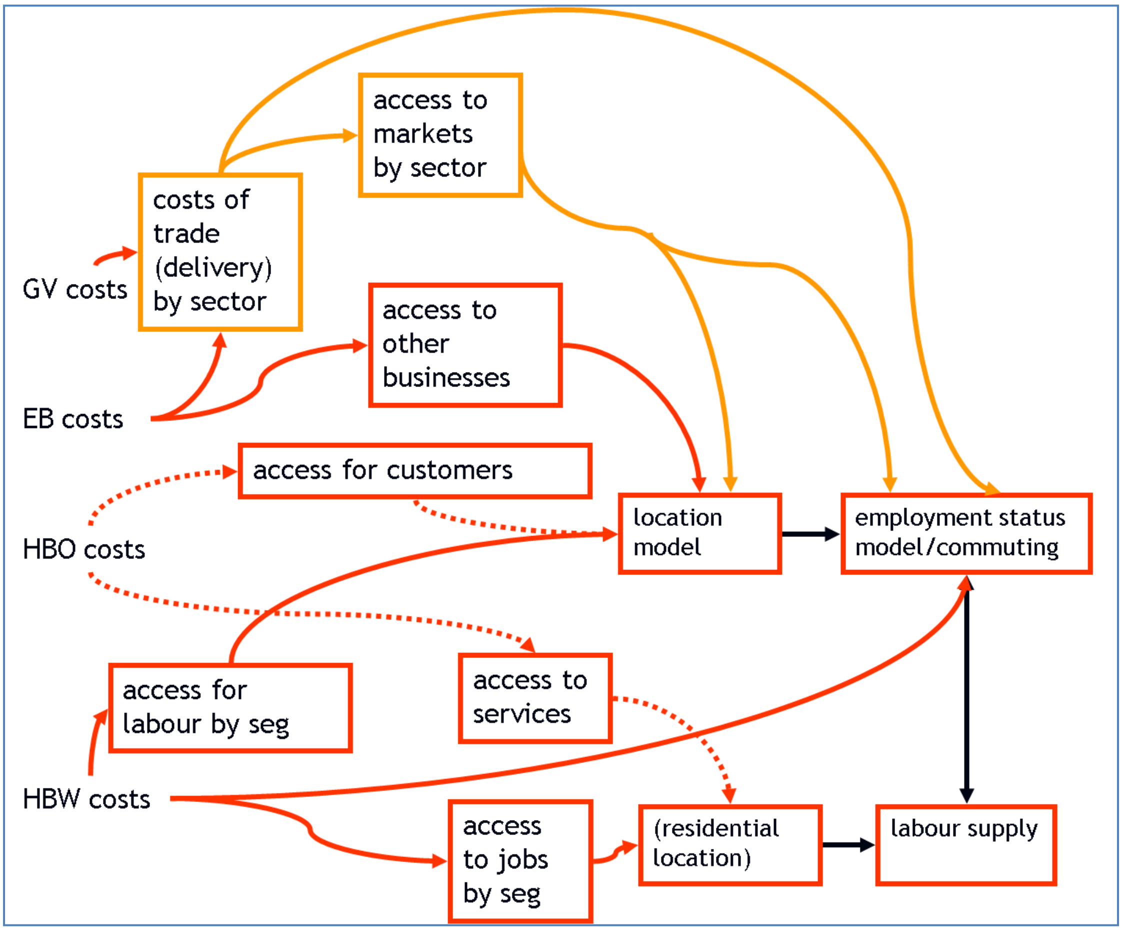
12.2.1 The costs that are passed from the transport model to the land use model are disaggregated by purpose. These include costs for Goods Vehicle movements (separately for Other Goods Vehicles and Light Goods Vehicles), business related trips, commuting trips between home and employment location and other trips from home, including trips to shops and other services. The costs have an influence upon both employment and household location, and as such are mentioned at a number of key points in the following paragraphs. Figure 12-1 summarises how the different transport costs from TMfS12 feed into accessibility measures and thence into components of the TELMoS12 land use model.

12.3 Accessibility calculations by measure

12.3.1 The first stage in the accessibility calculations is carried out by program AC12. This takes as input:

- the matrix of generalised costs for different purposes, by mode, from the most recent year of the transport model
- vectors of production and attraction weights, derived from the current TELMoS land use model database
- destination choice coefficients, plus (for passenger travel) modal constants and mode choice coefficients

Figure 12-1 Use of generalised cost data in accessibility calculations



GV = goods vehicles, EB = employer's business, HBO = home-based other, HBW = home-based work

12.3.2 These data and coefficients are used to calculate origin and destination accessibility measures for each combination of purpose and weights defined in the accessibility definition file. The accessibility definition file specifies seven pairs of accessibility measures. Each pair consists of two distinct measures which are calculated for each zone:

- an origin (or active) accessibility, which quantifies how difficult it is (in time, money and convenience) for residents in the zone to reach possible attractions (eg jobs)
- a destination (or passive) accessibility, which quantifies how difficult it is for residents to reach destinations in the zones

12.3.3 The definitions of the seven pairs of measures are shown in Table 12-1. Commuting is split into two pairs of measures according to socio-economic level[7].

[7] see TN2, version 3.01, Table 3-3

Table 12-1 Definitions of accessibility measures

Measure	Name	Destination weights (see note below)	Origin weights (see note below)	Trip purpose supplying generalised costs for these accessibilities	Choice Hierarchy
1	Commuting SEL 1	Employment SEL 1	Working residents SEL 1	1- Commuting	1
2	Commuting SEL 2	Employment SEL 2	Working residents SEL 2	1- Commuting	1
4	Business	Total employment	Resident population	3-Business	1
3	Shopping	Retail floorspace	Resident population	2-Other	1
7	Education	Number of resident children	Resident population	2-Other	1
5	Light Goods Vehicles	Total employment	Total employment	4-LGV	0
6	Other Goods Vehicles	Total employment	Total employment	5-OGV	0

Note:

"**destination** weights" are used to measure destinations in origin (active) accessibilities, ie when calculating "expected generalised cost of getting from the zone to..."

"**origin** weights" are used to measure origins in calculating destination (passive) accessibilities, ie when calculating "expected generalised cost of this zone being reached by...").

12.3.4 The accessibility calculations themselves are shown in the Appendix A.2, which explains the different hierarchy calculations. The destination and mode parameters used are shown in and are input in blocks ACIN01 and ACIN02 respectively. The coefficients used in the accessibility calculations are values for mode and destination choice which DSC (and others) have used in a range of studies dating back to the 1990 Edinburgh JATES study.

12.3.5 The accessibility calculations include constants which are specified as the natural logarithms of the totals of the corresponding weights in the base year. These ensure that the accessibilities measures will show improvement as a result of increases in the total opportunities, as well as from transport schemes that reduce the cost, time or inconvenience of travel.

12.3.6 The accessibilities are calculated in units of generalised cost, so an increase in any one measure means that accessibility has got worse.

12.4 Accessibility calculations by activity - household activities

12.4.1 The second stage in the accessibility calculations is carried out by program IA12. This takes values of zonal accessibility for each activity from the accessibility measures calculated by AC12. The DELTA activities[8] are separated into two groups for this purpose; household activities (explained in this section) and employment activities (explained in the following section).

[8] see TN2, version 3.01, para 3.1.02

12.4.2 For households, this is done by multiplying the different accessibility measures by the expected frequency (trips per household per week) for each individual household activity. This is achieved by breaking each household category down into its constituent members (i.e. number of children, working adults etc.) and predicting how many trips per week by each measure each household member will make. This is then summed by measure to find the total number of trips by each measure that each household type is predicted to make.

12.4.3 The accessibility value for a household therefore represents an expected generalised cost of travel per week. The differences between household types arise from the differences in household composition and in the types of trips they are likely to make. For households with working-age members, the trips rates assume a high level of employment, i.e. it is assumed that improving accessibility will be attractive to households even if they are currently unemployed; unemployed households ability to respond will of course be limited by lower incomes.

12.4.4 The way in which households perceive "accessibility" in making location decisions is an under-researched area, and hence the assumptions implemented are based on theory and judgement rather than on empirical analysis. However, it has been shown in work elsewhere that the kinds of accessibility measure used in DELTA are both:

- an influence on household location (see Revill and Simmonds, 2011[9])
- an influence on housing prices (see Ismail, 2005[10])

12.4.5 The inputs defining household accessibilities in terms of different measures of more specific accessibilities form block ASOZ01, of the IA12<><>.INP file. This block is the same in all years.

12.4.6 The outputs from this aspect of IA12 are the household-related parts of block ASRV01 in the ASRV<><>.DAT file.

12.4.7 Program PL12 reads household accessibilities by car-ownership level from the ASRV<><>.DAT file and calculates the average over the different car-ownership levels, using the proportions of households in each car-ownership level in each zone as the weights.

12.4.8 PL12 also organizes data from different years to pass to the location model (program ML12): it brings together the averaged accessibilities for each household activity and zone for the years specified by the "before time-lag" and "after time-lag" input to the model definition file. The difference between the two values is the change in accessibility over time to which (amongst other things) households respond in the ML12 location model.

12.5 <u>Accessibility calculations by activity - employment activities</u>

12.5.1 Accessibility measures for employment activities are based on varying combinations of:

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[9] Revill, E and Simmonds, D (2011): Calibrating a Household Relocation Model for Leicestershire. European Transport Conference, 2011.

[10] Ismail, S (2005): Hedonic Modelling of Housing Markets using Geographical Information System (GIS) and Spatial Statistics: A Case Study of Glasgow, Scotland. Unpublished PhD dissertation, University of Aberdeen Department of Land Economy.

- accessibility to the labour force (by socio-economic level)
- accessibility to consumers
- accessibilities to other businesses, for varying proportions of business travel, LGV movement and OGV movement

12.5.2 The inputs for employment activities similarly calculate the total travel associated with employment, as trips per worker. They also use values of time to convert the result into money units, so that the accessibility terms used in the utility of location for employment are all in money terms.

12.5.3 The weights on different types of accessibility (further broken down by car-ownership level) are specified in block ASDZ01 of the IA12 input file. This block is different in different years, because the values of time change over time; different values are specified for each transport model year.

12.5.4 The outputs from this aspect of IA12 are the employment-activity lines in block ASRV01 in the ASRV<><>.DAT file.

12.5.5 PL12 does the same job of organizing time-lagged accessibilities for employment activities as for household activities, so as to supply ML12 with values that can immediately be used to find the change in accessibility to which employment location is responding in the current year. PL12 does not have to do any averaging over car-ownership levels for employment activities' accessibilities, since that has already been done within IA12.

13 DEVELOPMENT MODEL

13.1 Overview

13.1.1 The development sub-model forecasts changes in the quantities of floorspace available to activities. It forecasts the development decisions made during each modelled period. It represents the processes by which firstly new floorspace is added to the stock within zones (within the Fully Modelled Area) and secondly existing floorspace is demolished. An identical approach is taken to the modelling of floorspace for each of the land uses that are modelled within TELMoS.

13.1.2 The outputs from the model are:

- a database describing the stock of floorspace within each zone
- information on the quantity of floorspace under construction
- the quantity of permissible development not taken up within each zone

13.1.3 The formulae used within this model are shown in Appendix A.5.

13.2 Development model MD12

13.2.1 The model works in three steps, separately for each floorspace type in each year. The three steps are:

- calculation of the total quantity of floorspace that developers would seek to construct, if not constrained by the planning system
- reducing that total to reflect the overall constraining effect of the planning system, if it is forecast to have such an effect
- allocating the total to zones

13.2.2 The DELTA package allows the development model to work either:

- calculating total development at Fully Modelled Area level, and distributing that to zones across the Fully Modelled Area (this version is described as the National Model)
- calculating total development for each individual Area, and distributing it to the zones within that (this version is known as the Area Model), or
- with a combination of the National Model and the Area Model

13.2.3 TELMoS applies the third, combined approach. We believe that this most adequately reflects the nature of development in Scotland where there is a mix of development processes, with some construction being of national) significance and others meeting more local need.

13.2.4 The proportion of new floorspace developed by the Regional model and the proportion developed by the Area model vary by land use type.

13.2.5 We aimed to calibrate residential development such that two thirds of development comes from the regional model and one third from the area model, this reflects the fact that a large proportion of housing development is undertaken by developers working at a sub regional level rather than independent builders. This target ratio has been informed by RICS research by Goodier and Pan (2010)[11].

13.2.6 Within commercial floorspace types we have aimed for around 67% of the developments made in response to the needs and requirements of the local market demands (in the area model) and about 33% of the total development reflecting regional decisions at the fully modelled area level. This split is a judgement based on the observation that a substantial proportion of commercial property development is bespoke building to accommodate expanding or changing local firms, or is driven by local landlords seeking to make best use of sites they own, and (though it obviously represents investment by the developers in question) is not part of the wider regional/national investment market.

13.2.7 At a practical level we believe that these assumptions will also produce stable development patterns across the modelled area.

13.2.8 The scale and location of developed floorspace is dependent upon the planning policy inputs. These are based upon information provided by the local planning authorities and define both the zones and the maximum amount of development that is permitted. The choice of which zones to develop in (from those where development is permitted) is dependent, in the regional model upon profitability (existing rents minus development costs where the development costs are converted into rent equivalent terms) and in the area model purely upon permissible floorspace.

13.2.9 When the development model models the decision to commence development within a zone it is important to remember that the resulting developed floorspace will not become available until a later period. The time lags are set in the model and are based on empirical records on construction periods. Developments under construction are therefore carried from each forecast year to the next.

13.2.10 The changes to the stock of each floorspace type will have an influence on both the employment and household location processes described above.

13.2.11 TELMoS's development model calculates the quantity of development that takes place within each zone in forecast years.

13.3 Development model – three steps

13.3.1 The first step in calculating the additional development is to calculate the total amount of development that developers would wish to construct (in the absence of any limits on planning permissions). This involves:

- in the National Model the quantity of new floorspace of each type is a fraction of the existing stock which varies according to average rent
- in the area model the quantity of new development is based upon a calculation of the additional floorspace that would be required if the households and employment activities were to occupy the floorspace at a level derived from the base year ratios of floorspace to households/workers (a level of 1.05 times the base year ratios has been used)

[11] Dr. Chris Goodier, Loughborough University and Dr. Wei Pan, University of Plymouth (2010): "The Future of UK Housebuilding" RICS Research Report 2010.

13.3.2 The second step involves the calculation of constrained development. This is a simple check against the total permissible development available in the area. If the unconstrained development is greater than the current total permissible development, it is constrained to that total; otherwise it is unchanged.

13.3.3 The final stage of the development model process is to allocate the additional development that is generated by the National and Area Development Models to zones and development processes. The hypothesis for this is that:

- development is likely to be concentrated in zones where it is expected to be more profitable
- other things being equal, development will be proportional to the amount of development permitted
- developers do not attempt to maintain a 'development land bank' in individual zones, i.e. development may take place up to the limit of what is permitted in any one zone

13.4 Development model outputs

13.4.1 To demonstrate the outputs we have plotted output from a working version of the reference case. These show:

- cumulative growth in floorspace forecast by the model (red line)
- cumulative growth in the activity (i.e. households or employment) that occupy that floorspace in the Do-Minimum Forecast
- cumulative potential growth in floorspace if all permissible development was developed (green line)

13.4.2 In all cases the data has been indexed with 2012 values being set to 1.

13.4.3 Showing the total potential development available (the green line) helps us identify which space categories have used up all the permissions and allocations.

13.4.4 Within TELMoS employment floorspace increases, for most space categories, in the first five years of the modelled period, this is the result of exogenous inputs provided by the districts and based on what has already happened. Thereafter employment floorspace growth is, where permissions allow, in line with the economic scenario.

13.4.5 All housing permissible development is used by the model (see Figure 6-1). In the period post-2031 the number of households continues to increase at a similar rate to the pre-2031 period. However there are relatively few permissible developments coming forward. Within the model this will be reflected in a decrease in vacant residential floorspace, increase in rents and a decrease in the floorspace per household ratio as households occupy less floorspace.

13.4.6 The retail floorspace shows that most of the permissible retail floorspace is built (Figure 6-2). The total quantity is greater than the increase in retail employment. Over the period to 2037 it also grows at a slower rate than the growth in consumer demand. This is in part that the quantity of permissible retail development acts as a constraint on growth in the period post 2026. In the period from 2014 to 2026 floorspace grows in line with consumer demand. In the period from 2012 to 2014 there is an increase in the quantity of retail floorspace in excess of the growth in consumer demand. This is due to the floorspace that is being made available in this period is treated as exogenous as described above.

13.4.7 Figures 6-3 and 6-4 show that office and industrial floorspace grow broadly in line with office-related and industrial-related employment. With both office and industrial floorspace only a small proportion of the permissible development identified is forecast to be built. In Figure 6-4 there is a decline in industrial-related employment post 2026, this reflects the economic scenario which has a constant total employment beyond that point but differing sectoral growth (with more growth in service employment and decline in manufacturing. No provision to remove industrial floorspace in line with this decline has been applied within the Do-Minimum forecast.

13.4.8 Figure 13-1 shows the forecast growth in leisure and hotel floorspace. Over the period to 2037 most leisure floorspace is built. The rate of growth is broadly consistent with the growth in leisure-related employment in the period post 2014. In that period employment grows by 12% and floorspace by 16%

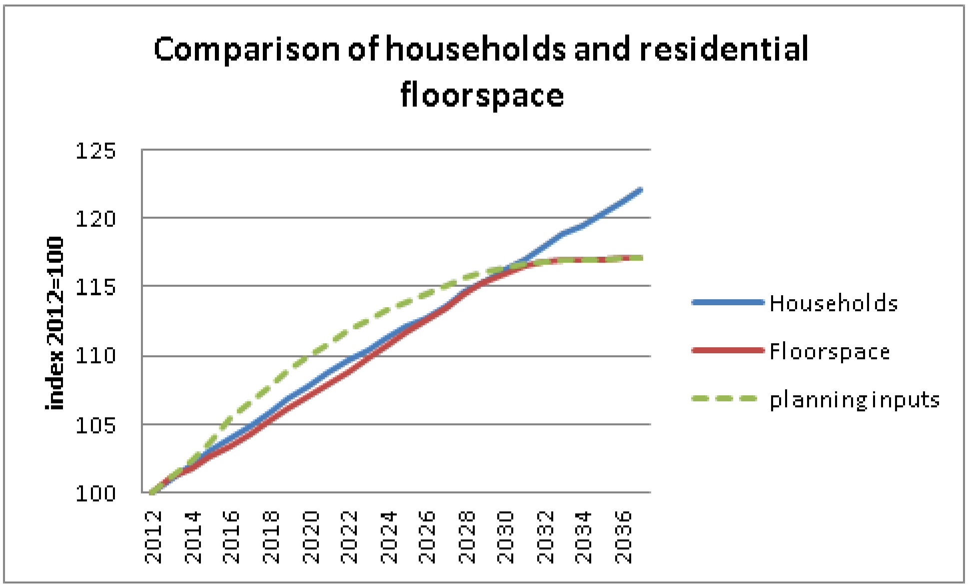

Figure 13-1 Growth in Housing Floorspace and Households

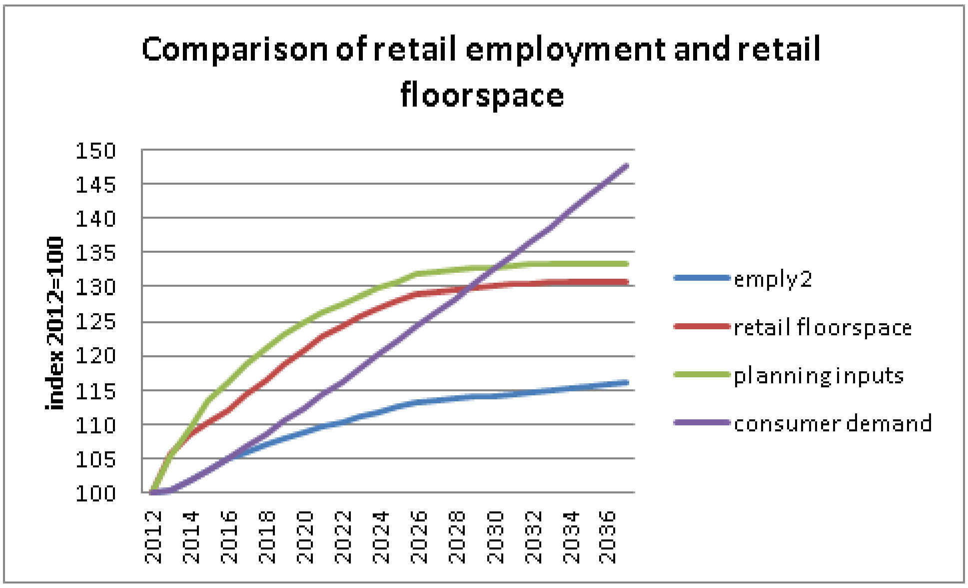

Figure 13-2 Growth in Retail Floorspace and Employment

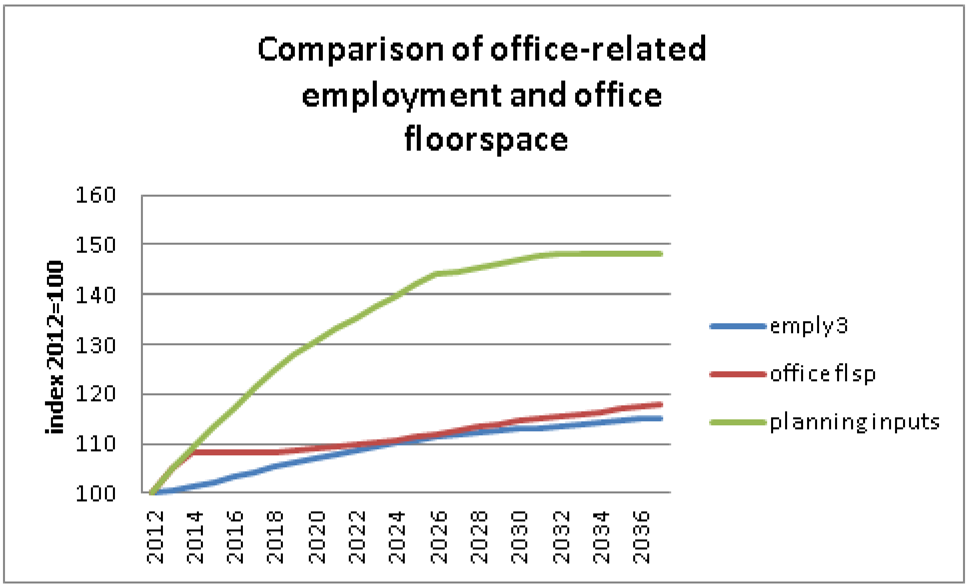

Figure 13-3 Growth in Office Floorspace and Employment

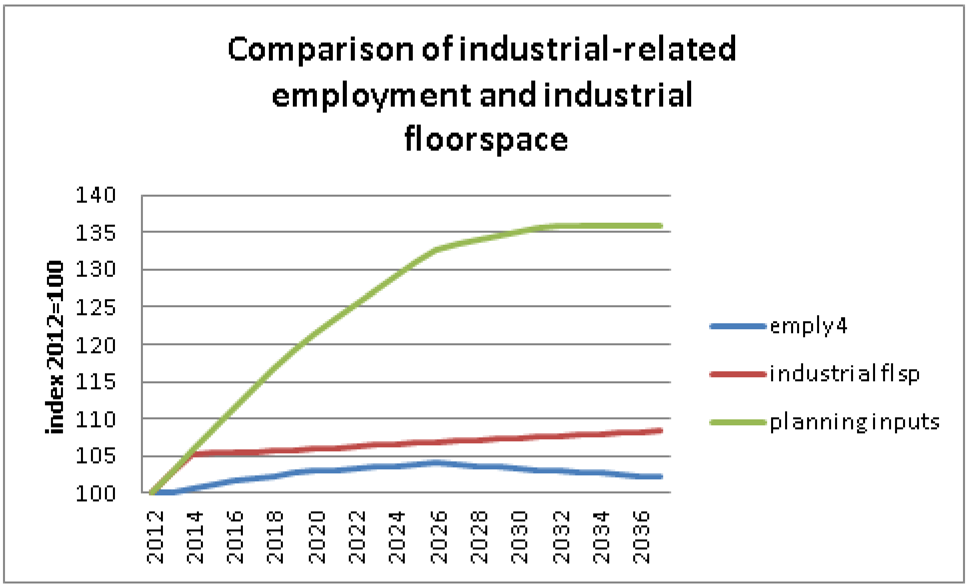

Figure 13-4 Growth in Industrial Floorspace and Employment

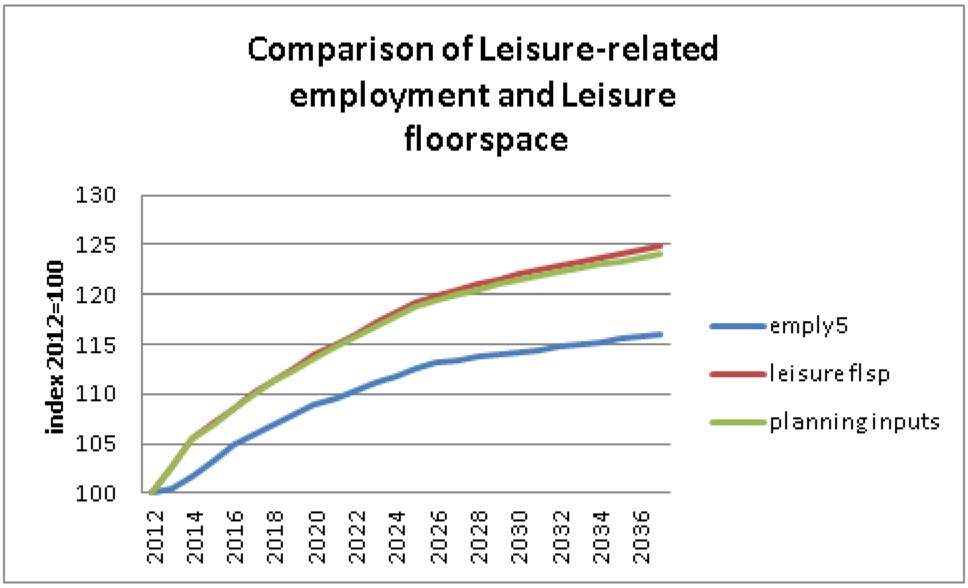

Figure 13-5 Growth in Leisure/Hotel Floorspace and Employment

14 HOUSEHOLD TRANSITION MODEL

14.1 Overview

14.1.1 The household transition model represents the processes by which the number and mix of household types change over each time period (i.e. each year). These changes are made by a combination of transition of households from one type to another (i.e. a single young adult becoming a single older adult), the dissolution of households (for example where two single households becomes one couple households and there is one less household), and household formation (for example where a grown up child leaves the family home to form a new household).

14.1.2 The outputs from the model are:

- the numbers of surviving households by type in each zone (ie households which have not dissolved or migrated away), split between mobile and immobile households
- the number of pool households by area

14.1.3 At this point the pool households are just the newly-formed households – migrant households are added to these later, by the migration model.

14.1.4 The formulae used in the transition model are given in Appendix A.6.

14.2 Introduction

14.2.1 The numbers of households in the model are updated each year by the household transition model. This implements the demographic scenario in terms of the numbers of households being formed or changing from one type to another (eg young couples becoming couples with children, or older couples becoming retired couples). That scenario was described in Chapter 8. The household types, and the person types used in classifying households, were described in Chapter 3.

14.2.2 This chapter describes how the scenario is implemented for households within TELMoS12, whilst Section 20.6 will describe the process for conversion of households to persons.

14.2.3 Demographic change is modelled in terms of:

- household transition (the process by which new households are formed, households cease to exist and other households evolve from one type to another (for example a household with two adults changes to a household with two adults plus child(ren) following the birth of their child)
- migration in and out of the modelled area

14.2.4 These are described below.

14.3 Household transitions

14.3.1 The household transition sub-model represents three main processes of change affecting households within the Modelled Area:

- household **formation** (block CTMT03 in file MT12<year><test>.INP);
- household **transformation** (block CTMT04); and
- household **dissolution** (block CTMT05)

14.3.2 All three processes are defined as the probability that a particular change will happen to a particular kind of household within a one-year modelled period. Formations are therefore defined as the probability that an existing household of one kind will "generate" a new household (usually of a different kind) within one year.

14.3.3 Some of the events modelled are represented by a single rate. For example, the probability that a couple's first child will be born during the year gives the probability of a simple transformation of the household from couple-without-children to couple-with-child(ren). Other events require two or more changes, the obvious example being that the marriage or cohabitation of two single persons is treated as the transformation of one household from single person to couple, and the dissolution of another single person household.

14.3.4 All the household transition processes are assumed to apply equally and independently to each socio-economic level. All of the calculations are simple applications of the relevant rates to numbers of households, carried out separately for each zone.

14.3.5 The calibration of the formation, transformation and dissolution rates was documented in Chapter 8.

14.4 Migration to and from the rest of the world

14.4.1 Rates for migrating to and from the Modelled Area are specified by household category.

14.4.2 These rates are input into block CTMT05 of the Transition model (MT12) input file.

14.5 Socio-Economic Levels

14.5.1 All these processes of demographic changes are assumed to apply equally and independently to the two socio-economic levels. All calculations are simple applications of the relevant activity rates to numbers of households, carried out separately for each zone.

14.6 Household sizes

14.6.1 Most of the components of TELMoS12 work with households rather than individuals. The numbers of persons by type in household of each type is used to convert the household data to population in the employment status model – see section 20.6.

14.7 Household mobility

14.7.1 The remaining function of the transformation sub-model is to define which households are "mobile" in the location sub-model. All newly-formed, newly-arrived or newly-transformed households are assumed to be mobile. In addition, a proportion of wholly unchanged households are assumed to be mobile; this represents mobility in the housing market which is unrelated to any change in household composition or status. These proportions are input in block CTMT07.

14.7.2 Note the outputs of the transition model are numbers of households by activity that

- are immobile in this period (by zone)
- may relocate ("mobile") in this period (by zone)

- must locate anew ("pool") in this period (by the area in which they are formed)

15 MIGRATION MODEL

15.1 Overview

15.1.1 The migration model models longer-distance household moves. It operates at the area level, rather than at the zone level. 'Push' and 'Pull' factors are calculated for each area based upon:

- the proportion of adults in work
- life-style factors
- rents

15.1.2 The outputs of this model – the movement of households from one area to another are an input to the household location model. There the households are included along with the other mobile and pool households and assigned to zones.

15.1.3 The mathematical specification of the migration model is described in Appendix A.8.

15.2 Introduction

15.2.1 The migration model deals with the longer-distance moves of households between areas within the Modelled Area. The inputs are illustrated in Figure 15-1.

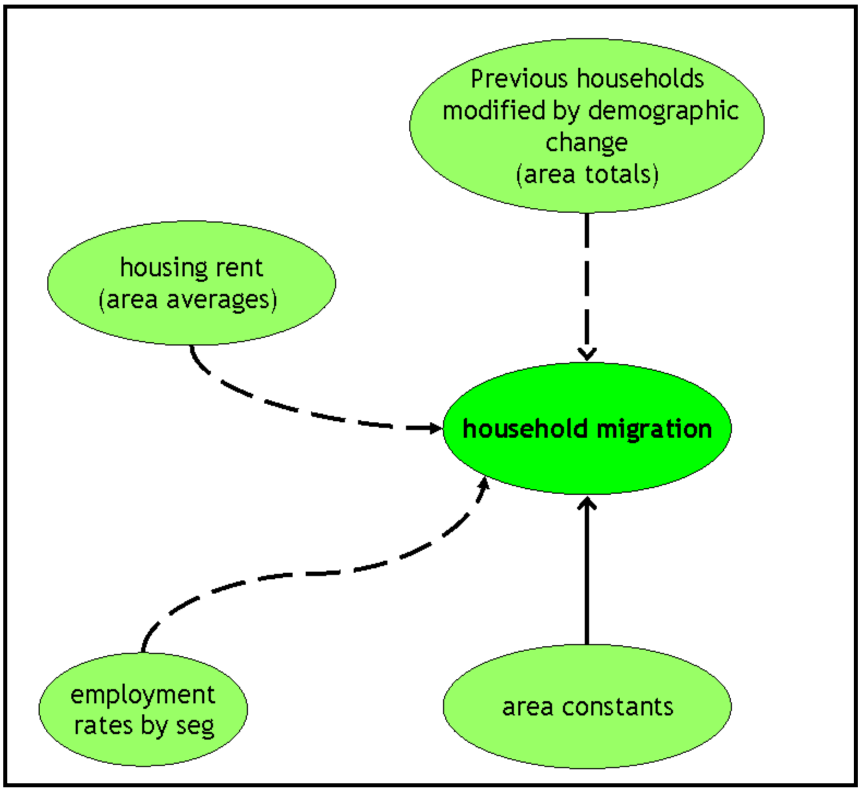

Figure 15-1 Migration model: inputs

15.2.2 The model works on the numbers of households (top of Figure 15-1) after other demographic changes have been calculated. The most important single effect is the tendency for households with working-age members to move from lower-employment to higher-employment areas (lower left); this is stronger than the other economic effect, which is the effect of housing costs (upper left), which to some extent discourage moves from cheaper to more expensive areas (and hence tends to act as a weak negative feedback to the employment-related moves, as high-employment areas tend to have higher housing costs than low-employment areas). Other effects are essentially "lifestyle" effects:

- younger persons tend to move towards higher-density areas
- older persons tend to move away from higher-density areas (typically to more suburban locations)

15.2.3 The variables driving these effects are input as area constants (lower right of Figure 15-1).

15.2.4 Research on migration based upon analysis of the Census and other sources has found that most household moves are over short distances, below the range of the migration model, and accordingly the migration model moves a small proportion of households in each year (a larger proportion are moved by the location model, which models short distance moves). Nevertheless it is an important part of the overall system. The number of households migrating is variable, so that, for example, a sharp change in employment levels in one area will change the rates of migration to and from that area.

15.3 The migration model

15.3.1 The migration model predicts the movement of households between the TELMoS land use model areas. The pattern of movement is determined by several variables, some of which are themselves predicted within the TELMoS land use model, whilst others are exogenous. The variables influencing migration patterns in the land use model are

- population density
- housing rents
- the proportion of adults in work

all by area.

15.3.2 The migration model is influenced by:

- the total number of households in the origin area
- the "push" factor for the origin area based upon the three variables described above
- the deterrence factor of the origin-to-destination distance
- the total number of households in the destination area
- the "pull" factor for the destination area again based upon the three variables described above
- an overall scaling factor

15.3.3 The following inputs are defined for each year:

- distance controls on the migration stream
- distance deterrence effect, and scaling of the migration flow

- weights on the different variables affecting migration

15.4 Distance controls on the migration stream

15.4.1 These controls in the MM12 input files specifies:

- the minimum distance for the modelled migration stream (Stream 2) is zero (ie migration is modelled between all area pairs, no matter how close together)
- the distance for full effect of the modelled migration flow is 40km

15.5 Distance deterrence and scaling of migration

15.5.1 The model takes inputs for different household categories to specify:

- the deterrence effect of distance
- the scaling of the migration flows

15.5.2 The deterrence coefficient is to be adjusted.

15.5.3 The scaling factor has different values by household type, which were estimated so as to obtain a reasonable mixture of migrants by age

15.6 Weighting migration-influencing variables

15.6.1 This input takes a set of coefficients to weight the migration-influencing variables (population density, rent and proportion of adults in work) as "push" and "pull" factors. It seems reasonable to expect that the "push" and "pull" factors are the same variables with opposite signs, and this condition has been imposed in applying the model.

15.6.2 The "push" and "pull" variables are:

- the proportion of working-age residents in work, for non-retired households; this is calculated (from the most recent zonal database) for the socio-economic level to which the household type belongs
- the average rent of housing floorspace
- the population density variable

15.6.3 The proportion of working-age residents in work is a negative "push" variable and a positive "pull" variable, so that households tend to move from areas with lower probabilities of being in work to those with higher probabilities. These variables are calculated separately for each socio-economic level, and apply to the migration of all households except retired households.

15.6.4 The average rent is a (weak) positive "push" and negative "pull". This tends to discourage moves from low to high rent areas and conversely to encourage moves from high to low rent areas. This variable has been calibrated separately for younger and older households. The migration of younger households is less sensitive to rent, this is partly because they are likely to occupy less floorspace and partly because those who move to large cities are willing to pay more in rent for the benefit of living there. The population density has different effects for different households types:

- for young singles and young couples without children it is a negative "push" and positive "pull", i.e. these households are attracted to higher densities
- for older households, it has the opposite effect, if these households are attracted to lower densities – representing the tendency for families with children, and older households, to move from urban to suburban or rural areas

16 INCOME MODEL

16.1 Overview

16.1.1 Household location is strongly influenced by household incomes, so the income model is documented first.

16.1.2 The household incomes (ie the average income of the households of a given type in a given zone) are calculated by the income model (MI12) based on the household type and the average number of workers per household (if any) in that household type in that zone.

16.2 Approach

16.2.1 The variable-worker approach includes:

- inputting household incomes as a minimum plus a marginal rate per worker
- using these inputs to calculate the average income of each household activity in each zone based on the previous year's workers per household
- using that calculated income in MC12
- using that calculated income in ML12 as the "expected income" for households moving to (or remaining in) that zone

16.2.2 The household income y (for each zone and relevant activity) is calculated as $y = aw + b$, where a and b are input coefficients, and w is the workers-per-household in that zone and activity, calculated from the numbers of workers and of households read from the AVZN<><>.DAT file output for the previous year.

16.2.3 Figure 16-1 shows the income levels applied in the base year. These are based upon the values used in TELMoS07.

Figure 16-1 Income calculations 2012

Unit: £/hhld/week, 2012

Household activity	Minimum income	Marginal income per worker
1	123.51	154.40
2	92.52	268.78
3	130.18	163.37
4	96.17	275.53
5	167.30	0.00
6	251.43	0.00
7	166.70	130.43
8	96.20	223.14
9	180.69	158.11
10	160.71	273.62

Household activity	Minimum income	Marginal income per worker
11	180.00	157.94
12	161.43	271.61
13	209.64	151.03
14	170.43	265.33
15	254.33	0.00
16	404.22	0.00
17	144.88	102.76
18	125.88	157.89
19	170.53	107.93
20	144.67	172.09

Source: TELMoS:07 and TELMoS12 incomes based on analysis of Family Expenditure Survey data adjusted to household types.

16.2.4 Household activities 5, 6, 15, and 16 are retired households and are defined elsewhere as not having workers; the marginal income per worker is therefore irrelevant but input as zero.

16.2.5 In setting up the model for forecasting, the rates of income growth for each type of household are applied to the previous year's incomes to generate the input incomes (minimum income and marginal income per worker) for all the forecast years which goes into the LCMLV1block of the ML12 input files.

16.2.6 The rate of income growth is based on National GVA and household growth. These are based upon the economic and demographic scenarions described previously.

17 CAR OWNERSHIP MODEL

17.1 Overview

17.1.1 The car ownership model forecasts the changing levels of car ownership for each household type and zone. The model is based upon the DfT's National Car Ownership model.

17.1.2 The outputs from the car ownership model are the proportions of households of each type, in each zone, having 0, 1 car, 2+ cars.

17.1.3 These outputs are all that is produced by the car ownership model itself.

17.2 Introduction

17.2.1 The car ownership model predicts household car-ownership levels based upon the household structure, incomes and licence holding trends. Zonal probabilities of a household of a particular type (for example a single young adult or a retired couple, of a particular socio-economic level) owning no car, or one or more cars is calculated.

17.2.2 These calculations may influence the household location model. The accessibility of each zone for each household type is an average of different accessibilities by car ownership, weighted by the probability that a household, if it locates in the zone, will have a particular level of car ownership. Also, the average cost of car ownership is a competing demand on the household's income and may affect the size of the household's budget for accommodation.

17.2.3 The mathematical specification of this model is described in Appendix A.

17.3 Car ownership model: design

17.3.1 The car ownership model in TELMoS is based upon the Department for Transport's national car ownership model, NATCOP, developed by Whelan[12] (2001) following earlier work by MVA Consultancy, and subsequently updated. For DELTA the model has been adapted and converted into a zonal and incremental form. Car-ownership is treated as conditional on location. The model is applied separately to each household type in each zone. In the TELMoS car ownership model, the choice set for the household is a choice between "no car", "one car" or "two or more" cars.

17.3.2 The model therefore works in terms of the probability that a household of a particular type living in a particular zone owns zero, one or two or more cars. The absolute numbers of households by car-ownership can only be calculated once the household location model has been run.

17.3.3 The updated probability of car ownership is calculated as a function of:

- the previous car ownership
- geography: different coefficients for the effect of income on car-ownership, and different saturation levels, apply in more or less urbanized zones

[12] Whelan, G. (2001): *Methodological advances in modelling and forecasting car ownership in Great Britain*. Paper presented to the European Transport Conference, available at www.etcproceedings.org

- changes in driving licence holding
- changes in household income (see Chapter 16)
- car running ownership cost indices
- number of workers per households (see Chapter 20 for description of the Employment Status Model)

17.3.4 The changes in licence-holding and in cost indices are inputs defined as part of the economic/demographic scenario. Workers per household are taken from the most recent outputs of the employment status model. Income levels are defined as part of the scenario but include a component which varies with employment status. The model's response to policy therefore comes either from changes in household's employment status or from household relocation between zones.

17.3.5 The variables used in the model are shown in Table 17-1. Table 17-2 shows the household groups for which different coefficients apply. Table 17-3 shows the zone groups used in the car ownership model.

17.3.6 The numbering of variables, households groups and zone groups in those three tables is then used in Table 17-4, which shows the coefficients on the variables, and Table 17-5, which shows the saturation levels. The coefficients in Table 17-4 are used to calculate the linear predictor term shown in paragraph A.10.2. The saturation levels in Table 17-5 are used directly in the equation shown there.

17.3.7 Note that the NATCOP design and calibration included variables relating to company car ownership; these can also be included in the DELTA version. However the DfT inputs used for NTEM 6.2 assume no change in the company car ownership inputs. Variables that do not change over time add zero to the linear predictor term. The company car ownership terms are therefore irrelevant to the working model, and for simplicity have been omitted.

17.3.8 The coefficients shown in Table 17-4 and Table 17-5 were taken from NATCOP files (supplied to DSC by DfT from work on NTEM 6.2) and are assumed constant for all forecast years. Previous car ownership, workers per household and incomes are supplied from other parts of FLUTE. The remaining inputs are:

- the future values for the licence holding variable and the car running cost index in Table 17.6
- the future values of the index of car ownership costs, shown in Table 17-7.

17.3.9 The forecasts of licence holding for retired households are based upon a Scottish Government Transport Research Series publication[13]. A constant proportion of non-retired households are assumed to be licence-holding.

17.3.10 Note that a minimum absolute cost of car ownership is also a separate input to the location model (see Table 18-2).

[13] http://www.scotland.gov.uk/Publications/2009/05/13144419/13 Transport Research Series: Evaluation of National Concessionary Travel in Scotland

Table 17-1 Car ownership model variable numbering

Variable	Description
2	Income

Table 17-2 Household groups in car ownership model

Household Group	Description
-4	Young single
-5	Older single
-6	Retired single
-7	Single parent + child
-8	Young couple no children
-9	Older couple no children
-10	Couple with children
-11	Retired couple
-12	3 adults no children
-13	3 adults + child
-17	All Retired
-18	All Non Retired

Table 17-3 Zone groups in car ownership model

Zone Group	Description
0	
-94	Metropolitan Districts
-95	Urban (districts with a density greater than 7.9 persons per hectare)
-96	Sub-Urban (districts with a density between 2.22 and 7.9 persons per hectare)
-97	Rural (districts with a density less than 2.22 persons per hectare)

Table 17-4 Car-ownership coefficients, 1+ choice, 2+ choice, 3+ choice

Variable	Household Group	Zone group	Coefficients for car choice 1+ Choice	Coefficients for car choice 2+ Choice	Coefficients for car choice 3+ Choice
2	Young single	Metropolitan Districts	0.000163	1.5E-05	0
2	Young single	Urban	0.000195	2.08E-05	4.19E-06
2	Young single	Suburban	0.000233	2.49E-05	1.31E-05
2	Young single	Rural	0.00024	1.66E-05	3.22E-06
2	Older single	Metropolitan Districts	0.000163	1.5E-05	0
2	Older single	Urban	0.000195	2.08E-05	4.19E-06
2	Older single	Suburban	0.000233	2.49E-05	1.31E-05
2	Older single	Rural	0.00024	1.66E-05	3.22E-06
2	Retired single	Metropolitan Districts	8.01E-05	1.5E-05	0
2	Retired single	Urban	0.000112	2.08E-05	4.19E-06
2	Retired single	Suburban	0.00015	2.49E-05	1.31E-05
2	Retired single	Rural	0.000157	1.66E-05	3.22E-06
2	Single parent + child	Metropolitan Districts	0.000121	1.5E-05	0
2	Single parent + child	Urban	0.000154	2.08E-05	4.19E-06
2	Single parent + child	Suburban	0.000191	2.49E-05	1.31E-05
2	Single parent + child	Rural	0.000198	1.66E-05	3.22E-06
2	Young couple no children	Metropolitan Districts	0.000167	6.8E-05	0
2	Young couple no children	Urban	0.000199	7.39E-05	4.19E-06

Variable	Household Group	Zone group	Coefficients for car choice 1+ Choice	Coefficients for car choice 2+ Choice	Coefficients for car choice 3+ Choice
2	Young couple no children	Suburban	0.000237	7.8E-05	1.31E-05
2	Young couple no children	Rural	0.000244	6.97E-05	3.22E-06
2	Older couple no children	Metropolitan Districts	0.000167	6.8E-05	0
2	Older couple no children	Urban	0.000199	7.39E-05	4.19E-06
2	Older couple no children	Suburban	0.000237	7.8E-05	1.31E-05
2	Older couple no children	Rural	0.000244	6.97E-05	3.22E-06
2	Couple with children	Metropolitan Districts	0.000177	6.37E-05	0
2	Couple with children	Urban	0.000209	6.96E-05	4.19E-06
2	Couple with children	Suburban	0.000247	7.37E-05	1.31E-05
2	Couple with children	Rural	0.000254	6.53E-05	3.22E-06
2	Retired couple	Metropolitan Districts	0.000233	0.00011	0
2	Retired couple	Urban	0.000265	0.000116	4.19E-06
2	Retired couple	Suburban	0.000303	0.00012	1.31E-05
2	Retired couple	Rural	0.000309	0.000112	3.22E-06
2	3 adults no children	Metropolitan Districts	0.000119	9.3E-05	5.04E-05
2	3 adults no children	Urban	0.000151	9.89E-05	5.46E-05
2	3 adults no children	Suburban	0.000189	0.000103	6.35E-05
2	3 adults no children	Rural	0.000196	9.46E-05	5.37E-05

Variable	Household Group	Zone group	Coefficients for car choice 1+ Choice	Coefficients for car choice 2+ Choice	Coefficients for car choice 3+ Choice
2	3 adults + child	Metropolitan Districts	0.000106	7.38E-05	3.91E-05
2	3 adults + child	Urban	0.000139	7.97E-05	4.33E-05
2	3 adults + child	Suburban	0.000176	8.37E-05	5.22E-05
2	3 adults + child	Rural	0.000183	7.54E-05	4.23E-05

Table 17-5 Saturation Levels for Household groups

Household Group	Zone Group	Car- ownership level	Saturation Level
Young single	Metropolitan	1 car	0.8991
Young single	Metropolitan	2 Plus cares	0.3056
Young single	Urban	1 car	0.8991
Young single	Urban	2 Plus cares	0.3056
Older single	Suburban	1 car	0.8991
Older single	Suburban	2 Plus cares	0.3863
Older single	Rural	1 car	0.8991
Older single	Rural	2 Plus cares	0.3863
Retired single	Metropolitan	1 car	0.8991
Retired single	Metropolitan	2 Plus cares	0.3056
Retired single	Urban	1 car	0.8991
Retired single	Urban	2 Plus cares	0.3056
Single parent + child	Suburban	1 car	0.8991
Single parent + child	Suburban	2 Plus cares	0.3863
Single parent + child	Rural	1 car	0.8991
Single parent + child	Rural	2 Plus cares	0.3863
Young couple no children	Metropolitan	1 car	0.8991
Young couple no children	Metropolitan	2 Plus cares	0.3056
Young couple no children	Urban	1 car	0.8991
Young couple no children	Urban	2 Plus cares	0.3056
Older couple no children	Suburban	1 car	0.8991
Older couple no children	Suburban	2 Plus cares	0.3863

Household Group	Zone Group	Car- ownership level	Saturation Level
Older couple no children	Rural	1 car	0.8991
Older couple no children	Rural	2 Plus cares	0.3863
Couple with children	Metropolitan	1 car	0.8991
Couple with children	Metropolitan	2 Plus cares	0.3056
Couple with children	Urban	1 car	0.8991
Couple with children	Urban	2 Plus cares	0.3056
Retired couple	Suburban	1 car	0.8991
Retired couple	Suburban	2 Plus cares	0.3863
Retired couple	Rural	1 car	0.8991
Retired couple	Rural	2 Plus cares	0.3863
3 adults no children	Metropolitan	1 car	0.8991
3 adults no children	Metropolitan	2 Plus cares	0.3056
3 adults no children	Urban	1 car	0.8991
3 adults no children	Urban	2 Plus cares	0.3056
3 adults + child	Suburban	1 car	0.8991
3 adults + child	Suburban	2 Plus cares	0.3863
3 adults + child	Rural	1 car	0.8991
3 adults + child	Rural	2 Plus cares	0.3863

Table 17-6 Driving Licence Holders

Driving Licence Holders		
Year	All retired Scaled	Non retired
2011	0.577292958	0.697443527
2016	0.677691733	0.697443527
2021	0.737303506	0.697443527
2026	0.779136329	0.697443527
2031	0.801098561	0.697443527
2034	0.809605327	0.697443527
2035	0.813614234	0.697443527
2036	0.817484585	0.697443527
2037	0.82122623	0.697443527

Table 17-7 Car ownership costs and Running costs

Car ownership costs index (for all households)		
Year	**Owning cost**	**Running cost**
2011	57.3	100
2012	55.22	100
2013	53.14	100
2014	51.06	100
2015	48.98	100
2016	46.9	100
2017	46.9	100
2018	46.9	100
2019	46.9	100
2020	46.9	100
2021	46.9	100
2022	46.9	100
2023	46.9	100
2024	46.9	100
2025	46.9	100
2026	46.9	100
2027	46.9	100
2028	46.9	100
2029	46.9	100
2030	46.9	100
2031	46.9	100
2032	46.9	100
2033	46.9	100
2034	46.9	100
2035	46.9	100
2036	46.9	100
2037	46.9	100

Table 17-7 Car ownership costs and Running costs

	2012	**2013**	**2014**	**2015**	**2016 onwards**
Owning cost	55.22	53.14	51.06	48.98	46.9
Running cost	100	100	100	100	100

17.4 Results of the Car Ownership Model

17.4.1 Figure 17-1 shows the change in households by car ownership category within TELMoS. Since the car ownership model itself forecasts probabilities of car ownership by household type, conditional on location, employment status and income, these results also reflect the demographic scenario (determining the number of households in each type), the location model (determining where they locate) and the employment status model (which in turn reflects the economic scenario, determining employment status and income).

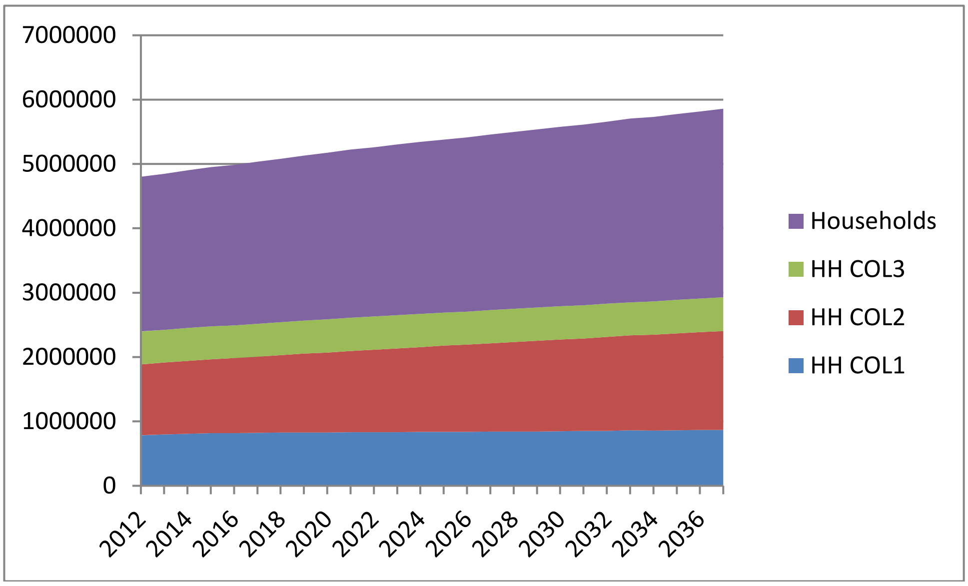

Figure 17-1 Results: households by Car Ownership Level

18 HOUSEHOLD LOCATION MODEL

18.1 Overview

18.1.1 The household location model assigns mobile households to zones. The mobile households in any one year consist of newly formed households (from the Transition model), long distance migrating households (from the Migration model) and that proportion of households who already are located within an Area but who will be looking to move (also calculated in the Transition model).

18.1.2 The key influences on location choice are accessibility, housing quality, available floorspace and the cost of location.

18.1.3 The outputs from the location model will be the number of households within each zone, the amount of occupied floorspace, the amount of vacant floorspace and the rent levels for floorspace (of each type).

18.1.4 An important and deliberate feature of this model is that households are conserved even if housing is in short supply; only the migration model can adjust the total number of households in the Modelled Area. In reality, the number of households is a complex response to demographic, housing and economic conditions[14]. At any one time there are many concealed households (individuals, couples or families who would like to live as separate households, but are obliged for financial reasons to live with others – most obviously, young adults living with their parents) and sharing households (separate households who share the essential facilities of a dwelling but are not otherwise living together), as well as single people who group together into temporary households in order to find housing they can afford. Modelling all of this is possible but complex and time-consuming both to implement and to run; it also makes it difficult to tell whether a scenario is consistent with the GROS scenarios or not. Our approach in the TELMoS land use model and most other DELTA models is therefore to take household formation as given and to treat housing as a continuous variable of housing floorspace.

18.1.5 In the model, the number of households in a zone can change even if there is no change in the supply of housing or in the vacancy rate, with households being reported as occupying more or less floorspace. In most cases, this would appear “on the ground” as an increase in the number of concealed households or in different kinds of sharing. This interpretation should be kept in mind.

18.1.6 Another modelling convention adopted to limit the complexity and run-time of the model is to model all households as if they were renting housing. This approach avoids the complexities of modelling owner-occupation separately from renting, and is widely used in urban economics (though not, obviously, in housing market studies).

18.1.7 It should be noted that we have developed a version of DELTA in which housing is represented as dwellings, each households occupies one dwelling, and different tenures (owner-occupation, private renting and social renting) are explicitly represented. We have previously suggested that this could be implemented for the

[14] See for example Bramley, G, H Pawson, M White, D Watkins and N Pleace (2010): Estimating Housing Need. Department for Communities and Local Government, London, November 2010.

TELMoS if a more detailed representation of housing and housing markets is required.

18.1.8 The formulae used within this model are described in Appendix A.11.

18.2 Introduction

18.2.1 The household location model deals with shorter-distance moves of households that are already-located within an area, and with the location within areas of newly-formed or newly-locating households such as those who have migrated from elsewhere.

18.2.2 Housing floorspace is treated as a continuous variable, with households being able to occupy more or less of it: if rents go up, they will occupy less, and vice versa. Modelling housing floorspace in this way avoids a lot of modelling complexities of how households actually fit themselves into dwellings. An increase in densities (i.e. less floorspace per household) associated with an increase in rents can be thought of as representing a mixture of:

- some persons who would otherwise have lived alone choosing (or being "forced") to share accommodation with others
- some grown-up children who would have lived independently continuing (or returning) to live with their parents
- locating households generally occupying slightly smaller dwellings than they would otherwise have done

18.2.3 Not all households locate or relocate in each year; younger households are more mobile, older households much less so. As a result only a minority of households and of the housing supply is considered in any one year of the model.

18.2.4 The model first calculates the numbers of households of each type that would be expected if the numbers simply changed in proportion to floorspace changes. For newly-formed and newly-locating households, the model distributes households of each type in proportion to the numbers of such households "expected", except that a higher proportion of households will be attracted to zones where:

- accessibility (to work and to services) is improving
- housing quality is improving
- floorspace per household is increasing
- the costs of location (rent multiplied by floorspace per households) are decreasing

18.2.5 There are of course inherent tensions here: households will be attracted to increasing space per household in a particular zone, but the result of that attraction will be more household competing for the available space and space per household not increasing so much. The model finds the very short-term trade-off between these different effects.

18.2.6 The inputs and the model process are illustrated in Figure 18-1. The numbers of households to locate are shown top centre. The accessibility and quality variables, coming from other parts of the model, are shown to the right. The calculations of the expected household numbers, determined by the available housing, the previously located households and the households to locate, are shown in the upper left. The lower left of the diagram represents the calculations which produce the cost of location and floorspace per household variables; the new values of these are affected by the rents which are calculated within the model in finding a limited and very short term equilibrium between the demand for housing (households trying to locate) and available housing. The process of adjustment to equilibrium is indicated by the blue arrows.

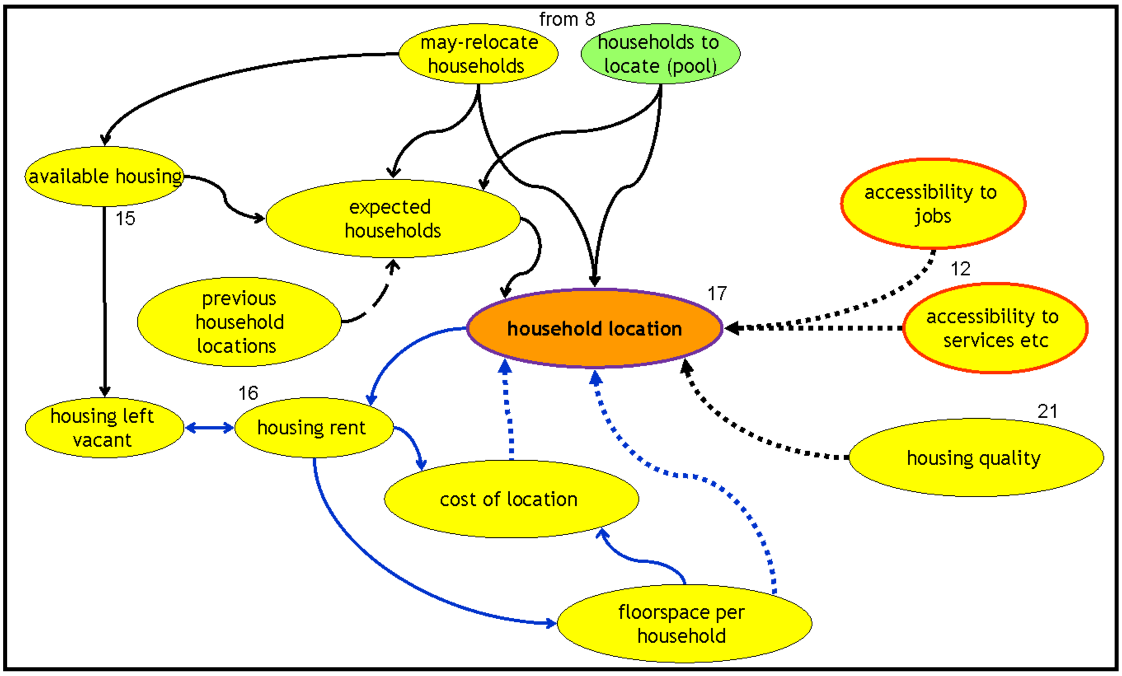

Figure 18-1 Household location model: inputs and process

18.2.7 The rent is adjusted to find the short-term balance between supply and demand, so that if (for example) accessibility is improving, the resulting increase in demand will lead to an increase in rents which will tend to reduce the floorspace per household and to increase the costs of location. The outcome in any one year is therefore the result of this interaction between rent and other variables. Different households have different accessibility variables and different sensitivities. An improvement in one zone in accessibility to work may therefore have a wholly negative impact on the location of retired households (in so far as these are moving at all), since they will not be attracted by better accessibility to work (which is not part of their accessibility calculation) but they will be affected by the increase in rents which will result from other households seeking to move into the zone.

18.2.8 For relocating households, i.e. those which have an existing location and (implicitly) the option of not moving, the model uses the same variables but to calculate redistribution from their existing location, with a strong distance deterrence effect. Relocating households will therefore tend to remain where they are unless there are significant effects to make them move to another zone – which is likely to be nearby rather than distant. These effects could be "push" effects (eg increasing rents in their present zone), "pull" effects (eg increasing quality in an alternative zone), or a combination of the two.

18.2.9 The mathematical specification of the household location model is described in Appendix A.11.

18.3 Household location model: design

18.3.1 The process of locating households includes a calculation of 'pool' households and 'mobile' households. The 'pool' households are those that do not have a previous location (i.e. they are newly formed households or new in-migrants to the area), the 'mobile' households are those with a previous location within the area. It follows that the 'pool' households have to be located whilst the 'mobile' households may be relocated.

18.3.2 The number of pool households (of a particular type) moving to a particular zone is a function of the pool households (of the same type) in the Area and the change in utility of location in the zone. The number of located 'mobile' households is a function of the number of households expected to relocate, the change in utility of location and a distance deterrence factor.

18.3.3 The cost of location is simply the rent multiplied by the floorspace per household.

18.3.4 The change in utility of location is a function of the changes in cost of location, accessibility, the quality of zone, the environment of the zone and the floorspace per household.

18.3.5 A time lag is modeled between changes in cost and floorspace and their impact upon location. The lag is defined in Table 18-4. The value describes the number of years prior that is used in calculating change (see section 0).

18.3.6 The **distance-deterrence function** is, as implied by the name, a measure of the distance-deterrence effect of the distance between each pair of zones (see section 18.8).

18.4 Household location model: coefficients and controls

18.4.1 The coefficients and controls used in the household location model are contained within the input file ML12<><>.inp. They are:

- consumption coefficients (minimum floorspace per household and the proportions of discretionary income spent on floorspace and on other goods and services)
- utility of location coefficients (coefficients on rent, accessibility, housing quality, environment and floorspace)
- the time lags of the location model, which define the periods of change to which household distributions are responding
- the coefficients of the distance deterrence function

18.5 Consumption coefficients

18.5.1 The main purpose of the consumption calculations is to forecast how much floorspace each household type will occupy if it locates in a particular zone, given the rent per unit of housing floorspace there. The floorspace per household is a minimum quantity plus the amount that the household can obtain for a given proportion of its discretionary income. Discretionary income is defined as

- net income
- **less** expenditure on minimum floorspace

- **less** a minimal cost of car ownership

18.5.2 Net income is provided by the income model (see chapter 16). The minimum floorspace per household and the proportion of discretionary income spent on housing are input coefficients based on judgement of what are plausible minima for floorspace per household, and on data from the Family Expenditure Survey on the split of expenditure between housing and other goods and services. These consumption coefficients are shown in Table 18-1, which also shows the proportion of discretionary income spend on other goods and services – this and the proportion spent on housing sum to one.

18.5.3 The cost of car ownership subtracted from net income in calculating discretionary income is the probability of car ownership multiplied by an estimate of the minimal cost of car ownership (Table 18-2). This cost represents the absolute minimum expenditure necessary to obtain the higher accessibility resulting from car ownership; additional expenditure on a more reliable, comfortable etc car is assumed to be part of the expenditure on "other goods and services".

Table 18-1 Consumption coefficients for households

Household activity/activity group	Minimum floorspace (m^2)	Proportion of discretionary income spent on housing	Proportion of discretionary income spent on other goods and services
Young Single-adult household, SEL1	22.76	0.20	0.80
Young Single-adult household, SEL2	36.22	0.09	0.92
Older Single-adult household, SEL1	21.54	0.20	0.80
Older Single-adult household, SEL2	35.23	0.09	0.92
Retired Single-adult household, SEL1	20.00	0.20	0.80
Retired Single-adult household, SEL2	28.28	0.20	0.80
Lone Parent with child(ren), SEL1	24.08	0.20	0.80
Lone Parent with child(ren) , SEL2	31.37	0.20	0.80
Young Couple Household, no children, SEL1	36.88	0.09	0.92
Young Couple Household, no children, SEL2	59.83	0.09	0.92
Older Couple Household, no children, SEL1	36.88	0.09	0.92
Older Couple Household, no children, SEL2	59.83	0.09	0.92
Couple Household with Child(ren), SEL1	43.61	0.09	0.92
Couple Household with Child(ren) , SEL2	65.68	0.09	0.92
Retired Couple Household, SEL1	28.61	0.20	0.80
Retired Couple Household, SEL2	43.83	0.09	0.92
3+ adult household with no children, SEL1	38.00	0.09	0.92
3+ adult household with no children, SEL2	59.72	0.09	0.92

Household activity/activity group	Minimum floorspace (m^2)	Proportion of discretionary income spent on housing	Proportion of discretionary income spent on other goods and services
3+ adult household with child(ren), SEL1	40.00	0.09	0.92
3+ adult household with child(ren) , SEL2	60.00	0.09	0.92

Table 18-2 Minimum cost of car ownership (£ per week)

Household activity	One car	Two cars	Three plus cars
All households	22.025	44.051	63.492

18.6 Utility of location coefficients

18.6.1 Our standard approach to arriving at values for the utility of location coefficients is applied in three stages. The first is to estimate the relative values of the coefficients on cost of location, accessibility and floorspace per household for each household type. The ratio of the accessibility coefficient to the cost coefficient can be interpreted as a "willingness-to-pay", and since accessibility is defined as expected generalised cost of travel, measured in minutes, this willingness-to-pay corresponds to a value of time. The relative value of accessibility to cost is accordingly fixed to a value of time. In the TELMoS land use model, the values of time for each household type have been estimated as a function of the modelled household incomes, adjusted so that the average values correspond with those being used in the transport model (averaged over the modelled period). There is scope for further investigation of how the values of time that may be implicit in households' location decisions relate to those implicit in their day to day travel decisions (as used in the transport model); in the absence of better evidence we assume that they are broadly comparable. The ratio of the coefficient on floorspace/household to that on cost is fixed in a similar way.

18.6.2 The second stage is to determine the absolute values of these coefficients. These values have been based on previous TELMoS07 model values.

18.6.3 The third stage is then to fix the coefficients on housing quality and local environment; this is done by running the location model with the fixed values for the 'thetas' on cost of location, accessibility and floorspace per household and initial values, and adjusting these two remaining coefficients so that a 0.01 change in quality has, on average, a 1% impact on rents – since the definition of the quality measure is that it will have that effect (in or around the base year).

18.6.4 The adjustment to fix the absolute values of the coefficients has been based on a mixture of:

- evidence from the calibration of previous static models implemented for Bristol and Merseyside in the early 1990s
- comparison of the impact of accessibility change on rents with results from hedonic price models
- our own judgement of the reasonableness of the resulting effects, considered both by analysis of the coefficient values and in the working model

18.6.5 The resulting values for the coefficients in the utility of location functions are shown in Figure 18-2. To recap, the five variables are the changes in:

- the cost of location (rent per m^2 of floorspace in the zone, multiplied by the number of m^2 that the household will occupy if it locates there)
- accessibility of the zone for this kind of household (from the accessibility calculations and the car ownership proportions)
- zonal quality (from the quality model and the assumptions about quality of new development)
- the environmental variables (from the environmental model)
- discretionary floorspace per household, ie the floorspace the household will occupy if it locates in the zones, minus the minimum quantity

18.6.6 The quality and environment variables are both implemented as indices related to the rent premium they are likely to generate (as explained in their respective chapters), but with higher (more positive) values of quality being **more** attractive, whilst higher values of the environmental value (based on traffic volumes) are **less** attractive.

Table 18-3 Utility of location coefficients, households

Activity description	**Utility of location coefficient (theta) on**				
	Cost of location	**Access**	**Zonal Quality**	**Environment**	**Disc. floorspace**
Young Single-adult household, SEL1	-0.0648	-0.03709	2.069	-2.069	0.026035
Young Single-adult household, SEL2	-0.0648	-0.03709	12.1655	-12.1655	0.026035
Older Single-adult household, SEL1	-0.0648	-0.03709	1.1586	-1.1586	0.026035
Older Single-adult household, SEL2	-0.0648	-0.03709	11.4207	-11.4207	0.026035
Retired Single-adult household, SEL1	-0.0648	0	0	0	0.026035
Retired Single-adult household, SEL2	-0.0648	0	6.2069	-6.2069	0.026035
Lone Parent with child(ren), SEL1	-0.0648	-0.01854	3.0621	-3.0621	0.026035
Lone Parent with child(ren) , SEL2	-0.0648	-0.01854	8.5242	-8.5242	0.026035
Young Couple Household, no children, SEL1	-0.0648	-0.01854	12.6621	-12.6621	0.026035
Young Couple Household, no children, SEL2	-0.0648	-0.01854	29.8759	-29.8759	0.026035
Older Couple Household, no children, SEL1	-0.0648	-0.01854	12.6621	-12.6621	0.026035
Older Couple Household, no children, SEL2	-0.0648	-0.01854	29.8759	-29.8759	0.026035
Couple Household with Child(ren), SEL1	-0.0648	-0.01854	17.7103	-17.7103	0.026035
Couple Household with Child(ren) , SEL2	-0.0648	-0.01854	34.2621	-34.2621	0.026035
Retired Couple Household, SEL1	-0.0648	0	6.4552	-6.4552	0.026035
Retired Couple Household, SEL2	-0.0648	0	17.8759	-17.8759	0.026035
3+ adult household with no children, SEL1	-0.0648	-0.00928	14.8965	-14.8965	0.026035
3+ adult household with no children, SEL2	-0.0648	-0.00928	29.7931	-29.7931	0.026035

Activity description	Utility of location coefficient (theta) on				
	Cost of location	Access	Zonal Quality	Environment	Disc. floorspace
3+ adult household with child(ren), SEL1	-0.0648	-0.00928	19.6965	-19.6965	0.026035
3+ adult household with child(ren) , SEL2	-0.0648	-0.00928	36	-36	0.026035

Note: these values are input to block LCML03 of file ML12<><>.INP

18.7 Time lags on household location variables

18.7.1 The time lags are input to block DF1103 in the definition file DELTAMOD.DEF and are shown in Table 18-4. Note that:

- for the utility of consumption variable, the change to which households respond is from *N* years ago to the present (so that the change is affected by the current rent values, which are found within the location model)
- for all other variables, the change is from *N+1* years ago to one year ago (ie change over the *N* years ending at the beginning of the present year

18.7.2 These coefficients are logically calculated as the inverse of the mobility rates, so if 20% of households of one type move in each year the lag on the utility of location must be 5 years.

Table 18-4 Time lags in household location model

Household activity		Utility of Consumption	Accessibility		Quality		Environment	
Activity group	Activity group definition	BLag	BLag	ALag	BLag	ALag	BLag	ALag
-4	Young single	-2	-3	-1	-3	-1	-3	-1
-5	Older single	-2	-3	-1	-3	-1	-3	-1
-6	Retired single	-5	-6	-1	-6	-1	-6	-1
-7	Single parent + child	-4	-5	-1	-5	-1	-5	-1
-8	Young couple no children	-7	-8	-1	-8	-1	-8	-1
-9	Older couple no children	-5	-6	-1	-6	-1	-6	-1
-10	Couple with children	-4	-5	-1	-5	-1	-5	-1
-11	Retired couple	-4	-5	-1	-5	-1	-5	-1
-12	3 adults no children	-7	-8	-1	-8	-1	-8	-1
-13	3 adults + child	-4	-5	-1	-5	-1	-5	-1

Note: Blag and ALag refer to Start and End lags respectively to be used in the absolute change calculation of the variables

18.8 Distance deterrence coefficients

18.8.1 The coefficients of the distance deterrence function are chosen such that, when combined with the effects of the migration model, 60% of moves are 8 kilometres or less. By setting the alpha coefficient almost to zero, moves of 20 kilometres or more are virtually prohibited within the household location model (but are allowed to occur via the migration model which deals with longer distance moves). This is consistent with analysis by Gordon and Molho[15], 1998.

18.8.2 The distance deterrence coefficients used in the TELMoS12 land use model are shown in Table 18-5 below.

Table 18-5 Coefficients on distance deterrence

Household activity	*Alpha*	*Beta*	*K*
All	0.000	-0.6	6.0

18.9 Household location model solution

18.9.1 The model takes as starting values:

- the previous year's rents
- the amount of vacant floorspace left from the previous year, plus new construction, less demolition and less any which is being deliberately held vacant (usually for future demolition)

18.9.2 Using these starting values it calculates both:

- the costs of location and the floorspace/household for each household type in each zone
- the resulting location/relocation of households

18.9.3 It then checks for each zone whether:

- the floorspace occupied by locating households (the numbers of households multiplied by the floorspace/household), plus the vacant floorspace

equals

- the quantity available to the location/relocation model (i.e. the total stock less that occupied by immobile households and any that is being deliberately held vacant)

18.9.4 This equality never holds true in the first iteration of a working model: either households are trying to occupy more floorspace than is available, or they are occupying too little and there is floorspace unaccounted for. The model then iterates:

- over inner iterations which adjust the rents (and hence deter or encourage households to locate in each zone) until the floorspace occupied equals that available at the current level of vacancy
- over outer iterations which adjust the level of vacancy depending whether the rent has gone up or down from the previous period

18.9.5 At the end of this process, the model outputs:

[15] Gordon, I R and I Molho (1998): A Multi-stream Analysis of the Changing Pattern of Interregional Migration in Great Britain 1960-1991, Regional Studies, Vol 32 No 4, pp309-324.

- households located to zones (to which the immobile households have to be added to get total households; no further changes of location take place in any one year)
- rent per m^2 of housing floorspace per zone
- vacant housing floorspace by zone
- floorspace/household by zone and household type
- other derived variables eg the cost of housing for households of each type in each zone

18.10 Results: household response to accessibility change

18.10.1 It is possible to compare the location model response to accessibility change with findings from research in the property economics field, specifically with the results of hedonic price or rent models. Hedonic property price models are regression models which attempt to explain property prices in terms of variables (often quite large numbers of variables) describing:

- the property itself
- its neighbourhood or immediate surroundings
- its accessibility to other parts of the city or region

18.10.2 The underlying theory is that the purchaser, in paying the observed price, is purchasing a bundle of “housing services” such as bedrooms, bathrooms, garages and garden space within the property; a quiet or noisy, leafy or wholly built-up neighbourhood; and more or less easy access to facilities and opportunities such as work, shopping, entertainment and so on. Hedonic rent analyses typically do the equivalent, with obviously different variables, for commercial property considered in pounds per square metre per annum.

18.10.3 For the residential market, the work by Ismail[16] (2005) on the Glasgow housing market is particularly helpful as her independent variables accessibility outputs from the Central Scotland Transport Corridor Study (CSTCS) LUTI model. These were calculated using the same formulae as in the TELMoS land use model. She estimated a number of different models, and found significant coefficients on the accessibility measure showing that an increase of one minute (implying an increase of one minute in the expected all-mode average travel time from the zone to all work opportunities) would reduce the value of an average Glasgow property by 1.7% to 2.4%.

18.10.4 We have calibrated the TELMoS12 land use model against this result by inputting random exogenous changes in accessibility of between -10 and +10 minutes into the model for all zones and all measures (in any one zone, the same change was applied to each measure). We then extracted the residential rent changes that occur as a result of these changes in the following year and regressed these against the changes in accessibility. The rent impacts in 2014 show the impact on housing demand, due to the changes in accessibility in 2013 modifying the preferences of locating or relocating households, before any other modelled consequences such as changes in

[16] Ismail, S (2005): Hedonic Modelling of Housing Markets using Geographical Information System (GIS) and Spatial Statistics: A Case Study of Glasgow, Scotland. Unpublished PhD dissertation, University of Aberdeen Department of Land Economy

employment or changes in floorspace supply can occur. The percentage rent changes are plotted against the accessibility changes Figures 18-2 and 18-3 for Scotland and Glasgow area respectively.

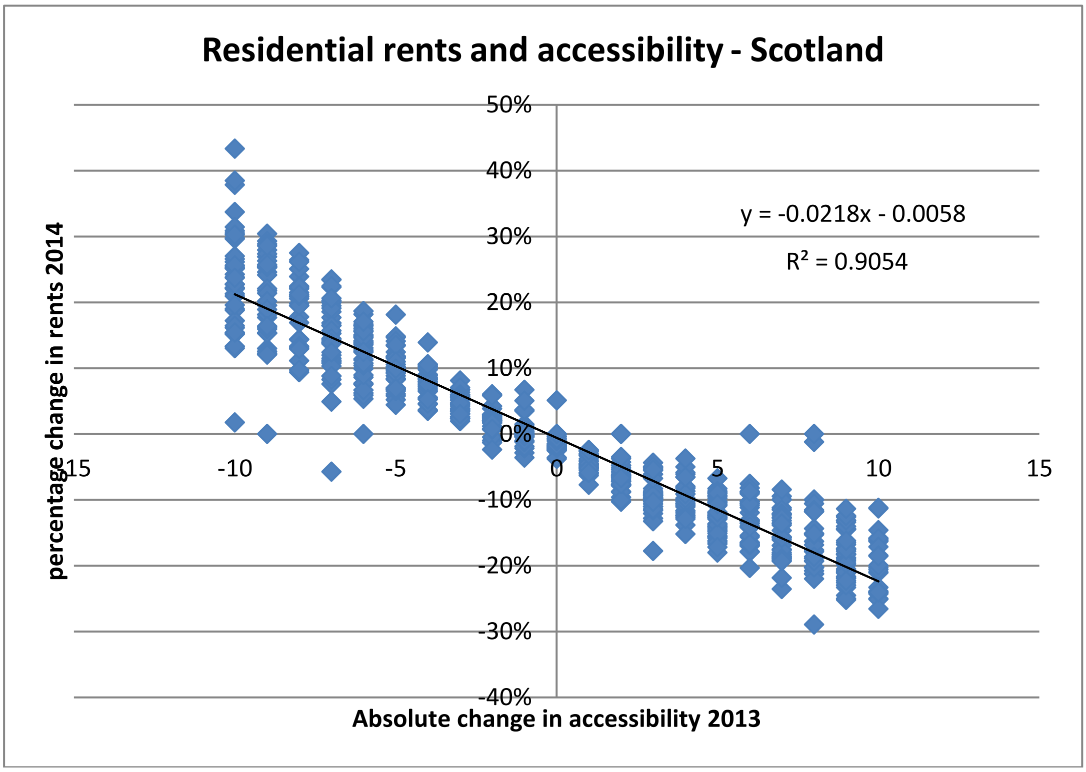

Figure 18-2 Percentage impact on rent compared to change in accessibility - Scotland

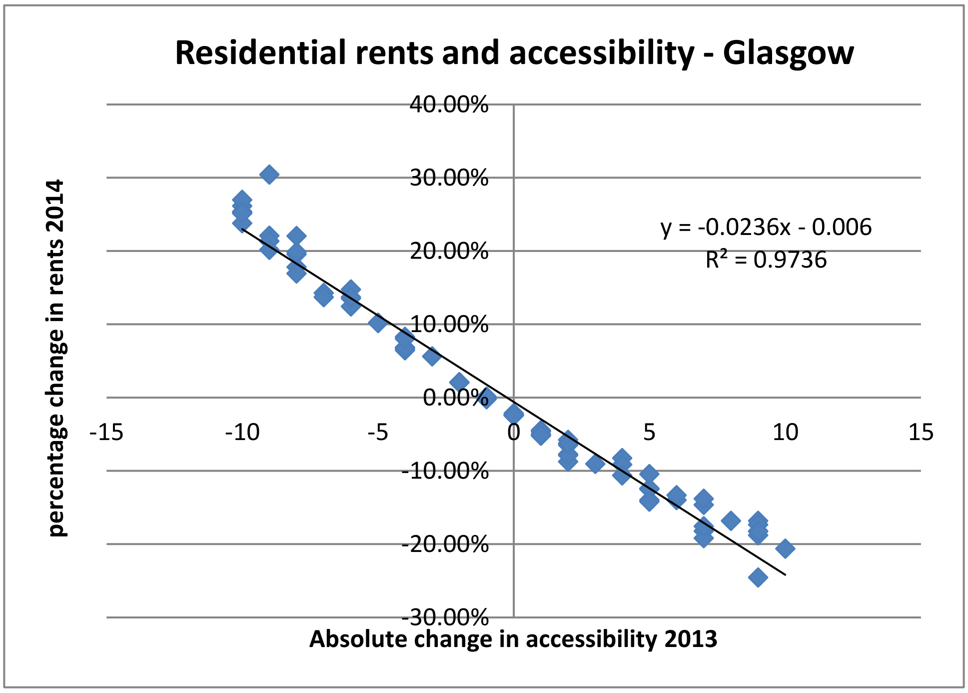

Figure 18-3 Percentage impact on rent compared to change in accessibility - Glasgow

18.10.5 Although the accessibility changes are the sole cause of the rent changes, the impacts on rents in individual zones are complicated by the facts that:

- household responses are affected by a number of accessibility measures, whereas in the regression we are plotting only the one most closely matching that which Ismail took from the CSTCS outputs
- the household responses are also affected by the mix of households in each zone and by the distance deterrence effect in household moves

18.10.6 Ismail's data was for Glasgow represents a physically much smaller geographic area than is modelled within TELMoS (ie Glasgow compared to Scotland). However, the household location model effectively works within areas (for "pool" households) or within the range controlled by the distance deterrence function (for relocating households). The comparison is therefore more appropriate than might at first appear.

18.10.7 In the results of the calibration, we have filtered out the Glasgow area as a control to check that the accessibility impacts on the rents fall in the upper range of Ismail's finding. The average impact on the whole of Scotland is expected to be slightly lower than Glasgow values though they should fall within Ismail's range.

18.10.8 There is, as we would expect, a very strong relationship between the accessibility changes and the rent changes, with an R-squared value of 0.97 for the Glasgow area and a 0.9 for the Scotland wide area. The slope of the regression line implies that an increase of one minute in the accessibility measure (ie a worsening of accessibility) is on average bringing about a decrease of 2.36% and 2.16% in housing rents in Glasgow and Scotland respectively. Both measures fall within the 1.7% to 2.4% range extracted from Ismail's analysis, this seems reasonable since it is expected that the effect would be strongest in Glasgow city, and considerably weaker in less urbanised areas. The analysis here covers the whole of the TELMoS land use model modelled area so includes a mix of large cities, smaller towns and less urbanised areas.

19 EMPLOYMENT LOCATION MODEL

19.1 Overview

19.1.1 The employment location model is similar to the household location model. It assigns mobile employment to zones. The key influences on location choice are accessibility, availability of commercial floorspace and the cost of location. Separate location models operate for each commercial floorspace type.

19.1.2 The outputs from the location model will be the number of jobs within each zone by sector and floorspace type, the amount of occupied floorspace, the amount of vacant floorspace and the rent levels for floorspace (of each type).

19.1.3 The formulae used within this model are described in Appendix A.12.

19.2 Introduction

19.2.1 TELMoS12 has an economic scenario that is based upon the CEBR employment forecast (see Chapter 8). Annual growth rates by sector are derived from Ernst & Young forecast and are then constrained to CEBR total employment forecasts.

19.2.2 The growth in employment is used to drive the demand for employment floorspace. This is calculated separately for each land-use type and within each zone. The location of employment is determined within the location model.

19.2.3 The zonal location model therefore represents decisions by firms on where to occupy floorspace. The employment status model (see Chapter 20) completes the calculation of the number of workers who will be located in each zone (both for newly-located and previously-located firms).

19.2.4 The distribution of employment within an area is strongly influenced by the availability of appropriate floorspace within each area (except for a few activities which do not use any modelled floorspace). New jobs and a proportion of existing jobs are modelled as locating, or potentially relocating, each year. A rent mechanism is used to model the competition for space, and the amount of space per worker can vary according to the rent per unit of space. The jobs using each type of floorspace will tend to locate in proportion to the available floorspace (including second-hand floorspace), except that:

- differences in floorspace per worker tend to persist over time, so zones with high ratios of floorspace per worker will continue to have high ratios unless rents increase
- more jobs will be attracted to zones where accessibility (to labour, to consumers, to other businesses – for which there are different measures for each activity) is improving
- more jobs will be attracted to zones where costs of location are falling

19.2.5 The costs of location for each employment activity in each zone are calculated from the rents, which themselves reflect the balance of supply and demand; the iterative calculations to find the current rents are indicated by the blue arrows in the lower left of Figure 19-119-1. So if the accessibility of a zone improves, demand in the zone will increase, rents will increase, and the increase in costs will partially offset the improvement in accessibility. (If planning policies permit, the increase in rents will also act as a signal to the regional development process to supply more space in this zone).

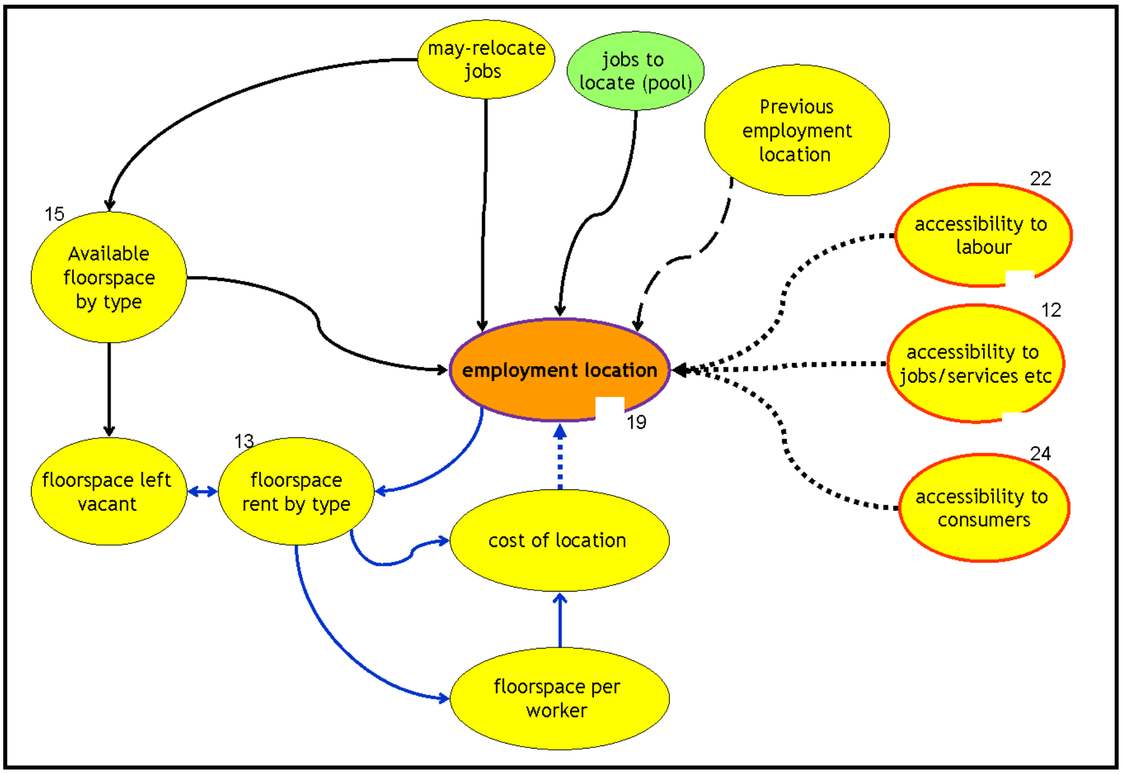

Figure 19-1 Employment location model: inputs and equilibrium process

19.3 <u>Employment location model: design</u>

19.3.1 There is in effect a separate location/property market model for each floorspace type and for the employment activities that occupy that type of floorspace; there are no direct interactions between these location/property market models when they run in any one year.

19.3.2 As with the household location model there are both "mobile" and "pool" jobs, "mobile" jobs having a location from which they move and "pool" jobs being those with no prior location.

19.3.3 The majority of employment location is a distribution of the "pool" of jobs of one activity to be located to the zones of one area in one year. Some employment is also redistributed from its initial location.

19.3.4 In both Pool and Mobile location, changes in distribution (compared with the previous distribution) tend to be strongly influenced by changes in the quantity of floorspace which landlords make available (which in general will vary as the rent changes) and rather less strongly by a utility term reflecting changes in cost, accessibility and the environment.

19.3.5 There are time lags that work in the same way as for households. Similarly the cost of location is calculated as the space occupied per employee multiplied by the cost per unit of floorspace.

19.4 Location model (ii) employment location: coefficients

19.4.1 This section deals with:

- elasticities of floorspace per worker
- employment location model in general

19.4.2 Block LCML02 of the ML12<><>.INP file specifies the elasticities to be used in adjusting the ratio of floorspace per worker. The assumptions on minimum floorspace per worker and elasticities of additional floorspace per worker with respect to rent used in TELMoS12 are shown in Table 19-1.

Table 19-1 Employment activity elasticities for adjusting ratio of floor per worker

Activity	Activity name	Spacefactor	Elasticity	Min Floor per activity (sqm)
31	A - Agriculture, hunting and forestry	1.01	-1	5
33	B – Fishing	1.01	-1	5
35	C – Mining and quarrying	1.01	-1	5
37	D – Manufacturing non manual	1.01	-1	5
38	D – Manufacturing manual	1.01	-1	10
39	E - Electricity, gas and water supply non manual	1.01	-1	5
40	E - Electricity, gas and water supply	1.01	-1	10
41	F – Construction non manual	1.01	-1	5
42	F – Construction manual	1.01	-1	10
43	G – Wholesale and retail trade, repairs (retail)	1.01	-1	7.5
45	G – Wholesale and retail trade, repairs (other) non manual	1.01	-1	5
46	G – Wholesale and retail trade, repairs (other) manual	1.01	-1	10
47	H – Hotels and restaurants	1.06	-1	7.5
48	I – Transport, storage and communications non manual	1.01	-1	5
49	I – Transport, storage and communications manual	1.01	-1	10
50	J – Financial intermediaries (financial management)	1.01	-1	5
51	J – Financial intermediaries (local financial services)	1.01	-1	5
52	K – Real estate, renting and business activities	1.01	-1	5
53	L – Public administration & defence, social security non manual	1.01	-1	5
54	L – Public administration & defence, social security manual	1.01	-1	10
55	M – Education	1.01	-1	5
56	N – Health and social work	1	-1	5
57	O, P, Q – Other non manual	1.01	-1	5
58	O, P, Q – Other manual	1.01	-1	10

19.4.3 The floorspace per worker at the current rent is multiplied by the current rent to obtain the cost of location for each employment activity in each zone; an allowance for other costs is also included. The resulting cost is one of the variables in the location choice model; the other is the accessibility for the activity, from the accessibility calculations.

19.4.4 Table 19-2 shows the coefficients on the changes in cost of location and accessibility in the employment location sub-model. Changes are measured over 6 years. Note that whilst the theta coefficients are the same in all cases, the cost and accessibility variables to which they apply differ considerably, so in practice sensitivities vary across sectors.

19.4.5 The theta coefficients are set to zero for those activities which do not use floorspace, the location of these activities is not modified by the location model.

Table 19-2 Coefficients of employment location model

Activity	Activity Description	Cost of Location Theta	Accessibility Theta
31	A - Agriculture, hunting and forestry (non manual)	-0.05	-0.04636
32	A - Agriculture, hunting and forestry (manual)	0.00	0.00000
33	B – Fishing (non manual)	-0.05	-0.04636
34	B – Fishing (manual)	0.00	0.00000
35	C – Mining and quarrying (non manual)	-0.05	-0.04636
36	C – Mining and quarrying (manual)	0.00	0.00000
37	D – Manufacturing (non manual)	-0.05	-0.04636
38	D – Manufacturing (manual)	-0.05	-0.03635
39	E - Electricity, gas and water supply (non manual)	-0.05	-0.04636
40	E - Electricity, gas and water supply (manual)	-0.05	-0.03635
41	F – Construction (non manual)	-0.05	-0.04636
42	F – Construction (manual)	-0.05	-0.03635
43	G – Wholesale and retail trade, repairs (retail)	-0.05	-0.00237
45	G – Wholesale and retail trade, repairs (other) (non manual)	-0.05	-0.04636
46	G – Wholesale and retail trade, repairs (other) (manual)	-0.05	-0.03635
47	H – Hotels and restaurants	-0.05	-0.03224
48	I – Transport, storage and communications (non manual)	-0.05	-0.04636
49	I – Transport, storage and communications (manual)	-0.05	-0.03635
50	J – Financial intermediaries (financial management)	-0.05	-0.04636
51	J – Financial intermediaries (local financial services)	-0.05	-0.04636
52	K – Real estate, renting and business activities	-0.05	-0.04636
53	L – Public administration & defence, social security (non manual)	-0.05	-0.04636
54	L – Public administration & defence, social security (manual)	-0.05	-0.03635
55	M – Education	-0.05	0.0017
56	N – Health and social work	-0.05	-0.0339

Activity	Activity Description	Cost of Location Theta	Accessibility Theta
57	O, P, Q – Other (non manual)	-0.05	-0.04636
8	O, P, Q – Other (manual)	-0.05	-0.03635

19.4.6 The coefficients of the employment location model have been taken from previous applications of DELTA, and tested as described in paragraph 19-8 below.

19.5 Employment location model: floorspace vacancy changes

19.5.1 The proportion of floorspace occupied varies according to changes in the rent – if rents fall, floorspace is more likely to be left vacant, and vice versa. The assumed elasticity of occupied floorspace with respect to rent is 0.5 for all floorspace types (input in block LCML06 of ML12<><>.inp) A minimum value is defined for the rent of each type of floorspace: if the rent falls to this value, the model calculates the amount of floorspace occupied at this rent, and simply assumes that all remaining floorspace is left vacant. The minimum rent is assumed to be half of the lowest rent in the base year.

19.5.2 Again these coefficients have been based upon previous applications and an appraisal of model responses.

19.6 Employment location model solution

19.6.1 The model is solved iteratively for each floorspace type in the same way as for households – see previous Section.

19.6.2 Employment activities that do not occupy floorspace do not use location cost variables. These are located by applying the location choice equations outside the iterative processes.

19.6.3 At the end of this process, the model outputs

- employment located to zones (to which the immobile employment has to be added to get total employment; no further changes of location take place in any one year)
- rent per m^2 of each type of floorspace per zone
- vacant floorspace by type and zone
- floorspace/job by zone and employment type
- various other derived variables eg the cost of location for employment of each type in each zone

19.7 Results: employment location response to accessibility change

19.7.1 In the same way as we have compared the TELMoS12 land use model housing rent responses to accessibility change with empirical research in Section 14.10 we have compared employment rent responses with the results from analysis by Dunse and

Jones (1998, 2005)[17] which looked at commercial rents for office and industrial property, again in the Glasgow area.

19.7.2 For this we have looked at the relationship between accessibility to other businesses and change in office and industrial rents. Overall the relationship is broadly consistent with the empirical evidence provided in the paper except in some very small zones where the small changes in demand resulting from the accessibility change were within the tolerance levels of the ML12 program, which therefore did not produce any rent adjustment.

[17] Dunse, N and C Jones (1998): *A hedonic price model of office rents.* Journal of Property Valuation and Investment, vol 16, no 3, pp 297-312. Dunse, N and C Jones (2005): UK roads policy, accessibility and industrial rents. In Adams, D, C Watkins and M White: *Planning, public policy and property markets.* Blackwell, Oxford.

20 EMPLOYMENT STATUS MODEL

20.1 Overview

20.1.1 The employment status model has three main functions. Firstly it takes the jobs by sector calculated in the employment location model and converts these to jobs by SEL. It then adjusts the labour supply by increasing the numbers of adults of working age in employment to match the labour demand, ie to match the number of jobs by SEL. Secondly it calculates the numbers of children and people in retirement within each zone. Finally it creates matrices of travel to work.

20.1.2 The outputs from the employment status model are the number of people by the four population groups modelled within DELTA (i.e. children, working-age adults in employment, working-age adults not in employment, retired), the number of jobs by socio-economic level and matrices of journey to work.

20.1.3 The formulae used within this model are described in Appendices A.13, A.14 and A.15.

20.2 Introduction

20.2.1 The employment status model, ME12, is the only DELTA sub-model which is primarily concerned with persons rather than households.

20.2.2 Within the TELMoS12 land use model it has been calibrated so that the total population and persons by type matches the 2010 GROS population projections.

20.3 Employment status model: functions

20.3.1 The employment status sub-model, ME12, has three main functions:

- to convert employment by zone and sector into employment by zone and socio-economic level, i.e. to calculate the demand for labour in terms which can be related to the supply of labour (i.e. to the number of located households)
- to adjust the numbers of persons in work to match the current demand for labour, given the changes in labour demand and supply, at the same time adjusting the travel-to-work matrices used within the land-use model
- to update the database for all categories of non-working persons

20.3.2 The last of these steps deals with:

- non-working, non-retired adults
- children
- retired persons

20.3.3 The calculation of the coefficients for persons by type per household by type was documented in Chapter 9 (Demographic scenario). Note that the category “retired persons” includes persons under pensionable age who have permanently retired and excludes persons of pensionable age who are still working. Changes in pensionable age are implicit in the demographic scenario.

20.3.4 The numbers of households by type and zone do not change within a run of ME12. The numbers of working-age persons are defined by coefficients estimated as part of the demographic scenario. The numbers in work are adjusted to match the numbers of jobs, the number of non-workers is the residual of the working-age population. The numbers of children and retired persons are not affected (within ME12) by jobs or the lack of jobs, but are calculated in ME12 simply because in the original DELTA model sequence it was the one program dealing with residents rather than households.

20.4 Convert employment by activity to employment by socio-economic level

20.4.1 The absolute number of jobs by area and activity is determined by applying the rates of growth in numbers of workers by SEL, area and sector as determined by the results of the REM. The distribution of these jobs is determined by the changes in job location (i.e. jobs by zone and activity) calculated in the location model.

20.5 Adjusting of residents-in-work and commuting

20.5.1 The application of the changes in jobs by zone and SEL to residents and commuting is essentially a scaling process. The following steps are undertaken:

- the commuting matrices for each SEL are adjusted in proportion to the changes in residents and car-ownership
- they are then rescaled to match the current numbers of jobs
- the numbers of residents in work are adjusted to match the numbers of workers being taken up by the commuting matrices
- there is a constraint for the maximum number of working and non working adults within each household type. If the adjustments result in the supply of workers matching or exceeding this constraint then the constraint is applied and the number of workers from other zones are adjusted so as to obtain the required numbers of workers

20.5.2 These inputs to ME12, contained in block CTME02, vary over time so as to replicate the demographic scenario for working age persons.

20.6 Children and retired persons

20.6.1 The average numbers of children and retired persons in each household type are exogenously input within Block CTME04 of ME12<><>.inp. These inputs to ME12 vary over time so as to replicate the demographic scenario for children and retired persons.

20.7 Travel-to-work adjustment

20.7.1 The final calculation undertaken by ME12 involves an adjustment to DELTA's travel to work matrix. The model reads in the transport model's redistribution of trips-to work resulting from changes to the generalised cost. It then adjusts these to take account of land use changes.

20.8 Results

20.8.1 The graphs illustrating the TELMoS12 model person forecasts including children, retired, workers and non workers from the Employments Status model ME12 are presented as part of the overall results of the demographic scenario described in Chapter 5.3.

21 THE RESIDENTIAL FLOORSPACE QUALITY MODEL

21.1 Overview

21.1.1 The quality model is applied to the residential floorspace[18]. It calculates changes in the area quality that result from other changes predicted by the model. As such it represents the effects that users of space can have on the characteristics of an area. The typical case is that the neglect of houses and their gardens by residents will reduce the attractiveness of the zone to potential residents; conversely, improvements (restoring gardens, planting trees) will increase it.

21.1.2 An initial index of quality has been calculated for each zone within the Fully Modelled Area. This remains unchanged from TELMoS07 (see Chapter 6). The average score on this index is 1.0. Those zones that have an above average quality have scores greater than 1 whilst those with a relatively poor quality (based upon the source data) have scores less than 1.

21.1.3 New residential developments are assumed to have a quality that is ten percent higher than that of the existing floorspace within the same zone. This reflects a judgement that new developments are generally of slightly higher quality than existing stock, though there may be exceptions.

21.1.4 The outputs from the quality model are updated values of the quality index for each zone.

21.1.5 Note that:

- quality values tend to rise over time, in line with incomes
- the exact effect of a change in the quality measure is determined by household location model, so the effect of a specific change in a specific zone will depend on the coefficients of the household location model and the interaction of that particular change with all the other effects at work in that model

21.1.6 The mathematical specification of this model is in Appendix A.16.

21.2 The Quality model

21.2.1 The sub-model represents the impact that residents have on the area in which they live, and hence the externality effects which residents' actions have on each other and on potential residents. The specific hypothesis implemented is that quality is positively influenced by residents with higher incomes (because they are more likely and better able to spend money on maintenance and improvement). The corollary is also true, that quality is negatively influenced by residents with lower incomes as they are likely to spend less on maintenance.

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[18] Quality **variables** may also be applied to commercial floorspace (we have for example used a quality variable to distinguish different standards of offices), but this was not part of the original proposal for the TELMoS land use model. Whether there should be quality **models** for commercial floorspace is debateable. In general the quality of the buildings and their immediate surroundings are less affected by commercial occupiers than dwellings and their gardens are affected by their residents. Partly of course this is because a high proportion of commercial property is rented, and standard tenancy agreements require the tenant to maintain the property without giving any incentive to make lasting improvements.

21.2.2 The quality effect is important for representing the way in which virtuous or vicious circles of change – in general, positive feedback mechanisms - can operate in urban areas. The effect is assumed to be strong but gradual. The sub-model therefore works by:

- calculating the average income per household
- calculating the "eventual quality" towards which the area will tend, given the present average income and occupancy level
- adjusting the current quality part of the way towards that eventual quality

21.2.3 Note that the impact of changing quality (the completion of the positive feedback loop) is dependent upon the coefficients in the utility of location function for households (see Chapter 18).

21.2.4 Table 21-1 shows the coefficients used in calculating the eventual quality.

Table 21-1 Housing quality model: coefficients for eventual quality

Source: own judgement regarding effects of income on quality

Variable	Value
Alpha (constant)	0.470773
Beta (coefficient on income)	0.0012

21.2.5 It is assumed that the change in quality in one year is one tenth of the difference between current quality and eventual quality. Both the eventual quality coefficients and the rates of changes are assumed the same for all forecast years.

21.3 Quality in the base year

21.3.1 The quality variable itself is defined such that in the base year, a value of one represents "average quality", a value of 1.1 represents quality which we believe would attract a 10% premium on rents or prices, etc.

21.4 Quality of new housing

21.4.1 When exogenous development is specified, the quality of the new floorspace that is being constructed is input exogenously too.

21.4.2 For exogenous development taking place in 2013 (the first year of the model forecast), the quality premium was recalculated so as to be 10% higher than the 2012 zonal qualities. This was to ensure that new development would still be developed at a quality premium over the existing stock in that zone.

21.4.3 Permissible development quality is calculated in a different way. Using a model option, the quality of new permissible development is input as 1.1 times the existing quality, thus giving new floor space the 10% quality premium over existing stock as already discussed.

22 REGIONAL ECONOMIC MODEL

22.1 Overview

22.1.1 The Regional Economic Model (REM) forecasts the growth (or decline) of the sectors of the economy in each of the DELTA Areas modelled. Its inputs include forecasts of overall growth in output and productivity.

22.1.2 The forecasts by sector and area are influenced by:

- costs of transport (from the transport model)
- consumer demand for goods and services (from the urban model)
- commercial rents (from the urban model)

22.1.3 The base year database, which was described in Chapter 6, draws on the most recently published economic statistics. In particular the Industry by Industry Matrix for 2009 contained within the Scottish Government Statistics publication 'Scottish Supply Use and Analytical Input-Output Tables, 1998-2009'[19]. This table contains information on the intermediate demand for each sector, final consumption demand (from households and government) and exports.

22.1.4 The overall level of growth is determined by the economic scenario (which was described in Chapter 9. This is based upon exogenous economic forecasts.

22.2 The Investment Model

22.2.1 The Investment Model's processes:

- allocates changes in capacity to each DELTA Area
- models investment and disinvestment decisions by sector

22.2.2 These processes subsequently affect the patterns of trade and production.

22.2.3 The investment model represents the processes of change affecting the productive capacity of each sector in each DELTA Area. Capacity has three direct effects within a DELTA model like TELMoS:

- it influences the patterns of trade and production (in the production model)
- it drives the changes in demand for non-residential floorspace (in the location model)
- a proportion of jobs are assumed to vary with changes in capacity rather than in production (in the employment status model)

22.3 The Production and Trade model

22.3.1 This model calculates the pattern of trade and the volumes of production by area, given data on final demands, prices and transport costs.

22.3.2 Within TELMoS12 the final demands are input exogenously and transport costs are generated within TMfS12.

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[19] http://www.scotland.gov.uk/Topics/Statistics/Browse/Economy/Input-Output/Downloads/IO1998-2009IxI

22.4 The Freight Model

22.4.1 This model converts the economic trades described above into physical flows (HGV flows). These flows are disaggregated into zonal matrices.

23 TELMOS12/TMFS12 INTERFACE

23.1 Introduction

23.1.1 The interface between TELMoS12 and TMfS12 is the same as in the previous versions.

23.1.2 This chapter documents the interface programs and files through which TELMoS12 passes information to TMfS12. The interface in the opposite direction is defined by the generalised cost files documented in Section 6.6 of this report..

23.2 Interface definition file

23.2.1 The interface definition file is used to specify a miscellany of information used in the DELTA/transport interface programs, including:

- information regarding the aggregation of the DELTA socio-economic levels;
- links between floorspace category and relevant TMfS journey purposes (notably shopping and education); and
- links between TELMoS activities and TMfS freight demand.

23.3 Interface programs and files

23.3.1 TELMoS12 uses a program, ITMFS, to tabulate DELTA outputs in the formats required by TMfS12. This outputs two files:

- TMfS<><>.CSV, containing zonal information on persons by person and household type; and
- TAV_<><>.CSV, containing zonal information on households and on employment in selected aggregations of sectors.

23.3.2 In addition the synthesized matrix of freight vehicle movements is passed from DELTA to TMfS12.

24 CONCLUSIONS

24.1.1 This report has described the processes adopted for creating the TELMoS12 model. This updates and calibration has used tried and tested processes that have been fine-tuned over the course of the development of other DELTA applications.

24.1.2 The structure of the DELTA model reflects research across a number of different disciplines including geography, planning, economics and transport. In implementing each component we have drawn upon this wider research both at a theoretical level and to assist in the calibration of model components.

24.1.3 The databases have been based on recent empirical records.

APPENDIX A MATHEMATICAL SPECIFICATION

A.1 Introduction

A.1.1 This Appendix sets out the main equations of the model, and explains some other aspects of the calculations.

A.1.2 The notation generally uses upper-case Roman letters for main variables (eg numbers of households), lower-case Roman letters for ratios or rates (eg the proportion of households dissolving in a one year period), and lower-case Greek letters for behavioural coefficients (eg sensitivity of households to changes in accessibility). Beware that the lower-case letters are recycled, ie alpha in one sub-model is probably not the same coefficient as alpha in another. (Where coefficients are used in more than one sub-model, this is indicated.)

A.1.3 All the calculations of changes are in terms of what happens during the one-year period *p* between time *t* and time *t+1*. For the first period *p*, *t* refers to the base year database; for all subsequent periods, it refers to the database written at the end of the preceding period. In addition to the conventional use of subscripts and superscripts, "postscripts" in brackets are used to denote subsets of main variables which undergo particular changes within a period *p*; for example:

- F_{tj}^{u} is the stock of floorspace type *u* in area *j* at time *t*;
- $F(N)_{pj}^{u}$ is a quantity of new floorspace type *u* to be built in area *j* starting in period *p*.

A.2 Accessibility calculations: accessibilities by measure

A.2.1 The calculations are standard logsum forms, related to the logit choice model widely used in transport modelling. The calculations depend on the choice hierarchy used. Note that the hierarchy in the accessibility calculations may not be the same as that in the transport model itself.

Hierarchy = 0, averaging of destinations only

A.2.2 This hierarchy applies when either:

- there is no mode choice to consider, at least for modelling purposes (eg for freight, where only road freight is represented), or
- the generalised costs of the alternative modes are already averaged in the file supplied to DELTA.

A.2.3 In this case the calculations to be done are the same as the second step of the hierarchy = 1 calculations, below.

Hierarchy = 1, destination above mode

A.2.4 With this hierarchy AC12 has to average the generalised costs over modes before calculating accessibilities by zone. This is done using the standard logsum formula:

$$g_{Tij}^{po} = \frac{1}{-\lambda_{Tij}^{Mpo}} \ln \sum_{m} \exp\left(-\lambda_{Tij}^{Mpo} . g_{Tijm}^{po}\right)$$

where

g_{Tij}^{po}	is the generalised cost from *i* to *j*, for purpose and car-availability level *o* in the most recent transport model year *T* – to be calculated;
g_{Tijm}^{po}	are the generalised costs from *i* to *j*, for purpose *p*, car-availability level *o* and mode *m*, for the most recent transport model year *T*;
λ_{Tij}^{Mpo}	is the mode choice coefficient for purpose *p* and car-availability level *o*. (It has *i* and *j* subscripts because it can vary with the distance from *i* to *j*.)

A.2.5 (Note that the result of this calculation is the same for each DELTA-modelled year from one transport model run to the next, but for simplicity the calculations are redone each year within the accessibility calculations.)

A.2.6 The second step is to find the accessibilities proper, as a weighted logsum average of the generalised costs to the possible destinations, the weights being the numbers of opportunities at each destination. Since these are forecast year by year, this part of the calculation has to be done for each year *t*, not just for each transport model year *T*:

$$A(O)_{ti}^{ao} = \frac{1}{-\lambda_T^{Dao}}\left(\ln\left\{\sum_j\left[W(D)_{tj}^a.\exp\left(-\lambda_t^{Dao}.g_{Tij}^{po}\right)\right]\right\} - K(O)^a\right)$$

where

$A(O)_{ti}^{ao}$	is the origin accessibility measure *a* for households of car-availability level *o* living in zone *i* at time *t*
g_{Tij}^{po}	is the generalised cost from *i* to *j*, for purpose *p* and car-availability level *o* in the most recent transport model year *T* – defined above;
$-\lambda_T^{Dao}$	is the distribution coefficient for measure *a* and car-availability level *o*; and
$W(D)_{tj}^a$	the current destination weight for zone *j* and accessibility measure *a*;
$K(O)^a$	is a constant specific to origin accessibility measure *a*.

A.2.7 The constant $K(O)^a$ is defined as the logarithm of the sum of the base year weights:

$$K(O)^a = \ln\sum_j W(D)_{(t=BaseYear),j}^a$$

A.2.8 This has the intentional consequence that increasing the total weights over time, i.e. increasing the total number of opportunities, will tend to result in improving accessibilities.

Hierarchy = 2, mode above destination

A.2.9 The first step is to calculate accessibility to destinations for each mode *m*, using the generalised costs for purpose *p* and the land-use weights *W* relevant to the accessibility measure *a* that is being calculated. For origin accessibilities this is done using the equation:

$$A(O)_{tim}^{ao} = \frac{1}{-\lambda_T^{Dao}}\left(\ln\left\{\sum_j W(D)_{tj}^a.\exp\left(-\lambda_T^{Dao}.g_{Tijm}^{po}\right)\right\} - K(O)^a\right)$$

where

$A(O)^{ao}_{tim}$	is the origin accessibility measure *a* for zone *i* and mode *m* at time *t*
g^{po}_{Tijm}	are the generalised costs from *i* to *j*, for purpose *p*, car-availability level *o* and mode *m*, for the most recent transport model year *T*
$-\lambda^{Dao}_{T}$	is the distribution coefficient for measure *a* and car-availability level *o*; and
$W(D)^{a}_{tj}$	the current destination weight for zone *j* and accessibility measure *a*;
$K(O)^{a}$	is a constant specific to origin accessibility measure *a*, as for hierarchy 1 (above).

A.2.10 The second stage of the origin accessibilities calculation for hierarchy 2 is to apply the logsum calculation to average these accessibilities by mode to an overall value

$$A(O)^{ao}_{ti} = \frac{1}{-\lambda^{Mpo}_{T}} \sum_{m} \exp(-\lambda^{Mpo}_{T} . A(O)^{ao}_{tim})$$

where

λ^{Mpo}_{T}	is the mode choice coefficient for purpose *p* and car-availability level *o*.

A.2.11 The results $A(O)^{ao}_{ti}$ are output in the ACOZ files.

A.2.12 The destination accessibilities $A(D)^{ao}_{ti}$ are found by similar formulae using origin rather than destination weights, and are written to the ACDZ files.

A.3 Accessibility calculations: accessibilities by household activity

A.3.1 Program IA12 sums accessibilities by measure to obtain accessibilities by household activity, still by car availability level *o*:

$$A^{ho}_{ti} = \sum_{a} A(O)^{ao}_{ti} . f^{ha}_{t} \qquad \text{1.3.2}$$

where

A^{ho}_{ti}	is the accessibility of zone *i* at time *t* for households *h* having car availability *o*
$A(O)^{ao}_{ti}$	is the accessibility measure *a* from zone *i* at time *t* for car availability level *o*
f^{ha}_{t}	is the weight on measure *a* for household type *h* at time *t*.

A.3.3 Program PL12 averages these accessibilities over car availability levels *o*:

$$A^{h}_{ti} = \sum_{o} A^{ho}_{ti} . p^{ho}_{ti} \qquad \text{1.3.4}$$

where

p_{ti}^{ho}	is the proportion of households *h* in zone *i* at time *t* having car availability *o*. (Note that in working out the accessibilities of zones to which households might locate, this is the conditional probability of having a given level of car availability i.e. what level of car availability the households *h* would be expected to have **if** they located in zone *i*).

A.4 Accessibility calculations: accessibilities by employment activity

A.4.1 For employment activities, the averaging over measures and car-ownership levels is done in one step by program IA12:

$$A_{ti}^{s} = \sum_{a}\sum_{o} A(D)_{ti}^{ao} \cdot f_{t}^{sao} \qquad (1.4.2)$$

where

A_{ti}^{s}	is the accessibility of zone *i* at time *t* for employment sector *s*
$A(D)_{ti}^{ao}$	is the destination accessibility measure *a* for zone *i* and car availability level *o* at time *t*
f_{t}^{sao}	is the weight for employment sector *s* on accessibility measure *a* for car availability level *o* at time *t*.

Area generalised costs and accessibilities

A.4.3 The zone-to-zone generalised costs are averaged across zone pairs to provide area-to-area costs by purpose. These are converted into costs of delivering the outputs of sector *s* from area *a* to area *z*, c_{taz}^{s}, by applying appropriate weights on the purposes.

A.4.4 The area accessibilities are calculated as a measure of the expected cost of delivering commodity *s* from production area *a* to consumption areas *z*:

$$A_{ta}^{s} = \frac{1}{\lambda_{t}^{s}}(\ln\sum_{z}\left\{W_{tz}^{s}\exp\left(\lambda_{t}^{s}c_{taz}^{s}\right)\right\} - L^{S})$$

where

A_{ta}^{s}	is the accessibility of area *a* at time *t* for employment sector *s*;
W_{tz}^{s}	is a weight describing the economic importance of area *z* for employment sector *s* at time *t*
λ_{t}^{s}	is a distribution parameter for employment sector *s* at time *t*
c_{taz}^{s}	is the (generalised) cost of delivering the outputs of sector *s* from area *a* to area *z* at time *t*.
L^{S}	is a constant (which may not be used).

A.5 Development and redevelopment model

A.5.1 The development model consists of the following steps, *applied separately for each floorspace type*:

- calculate the amounts of development (if any) that are permissible through redevelopment and/or intensification
- calculate the unconstrained amount of development that will (if possible) start as a result of the model-wide development process
- constrain that to the permissible quantity, if necessary
- allocate that development to zones and processes (ie new, redevelopment, intensification)
- calculate the unconstrained amounts of development that will (if possible) start as a result of the area-level development processes
- constrain those to the permissible quantity in each area, if necessary
- allocate that development to zones and processes (ie new, redevelopment, intensification) within each area

Fully Modelled Area total development, profit-led calculations

A.5.2 The general form of the model is:

$$F(U)^{u}_{p*} \;=\; \alpha^{u}_{p} \,.\, F^{u}_{t*} \,.\, \prod_{v} \left(\prod_{y=-4}^{y=0} \left(x^{vu}_{(t-y)*} \right)^{\beta^{vu}_{p}} \right)$$

where

$F(U)^{u}_{p*}$	is total unconstrained floorspace type *s* proposed to be started in period *p*
α^{u}_{p}	is a parameter scaling the whole equation
F^{u}_{t*}	is total floorspace type *u* existing at time *t*
v	is an index identifying a particular variable
y	is a timelag (years before time *t*)
$x^{vu}_{(t-y)*}$	is the value of variable *v* for floorspace type *u* in year *(t-y);* the * indicates that this if *v* is a zonal variable, the average value is used
β^{vu}_{p}	is a parameter for variable *v* with lag *y*

A.5.3 The unconstrained quantity $F(U)^{u}_{p*}$ is checked against the total permissible development, and if necessary reduced. The amount of development to be started after this check is the "constrained" quantity $F(C)^{u}_{p*}$.

Distribution of FMA total development (profit-led)

A.5.4 The distribution process allocates the "constrained" quantity $F(C)^{u}_{p*}$ both to zones and to "processes", where the processes are new build, redevelopment or intensification. This is applied using a conventional weighted logit formula, ie

$$F(N)^{du}_{pi} = F(C)^{u}_{p*} \,.\, \frac{F(P)^{du}_{pi} \,.\, \exp\left[\gamma^{u}_{p} \,.\left(r^{u}_{ti} - c^{du}_{pi}\right)\right]}{\sum_{d}\sum_{i} F(P)^{du}_{pi} \,.\, \exp\left[\gamma^{u}_{p} \,.\left(r^{u}_{ti} - c^{du}_{pi}\right)\right]}$$

where

$F(N)^{du}_{pi}$	the amount of new floorspace of type *u* in zone *i* started in period *p* through process *d*
$F(C)^{u}_{p*}$	is the (constrained) quantity of new floorspace type *u* to be started in period *p*
$F(P)^{du}_{pi}$	the current permissible development *d u* in zone *i*
γ^{u}_{p}	is the sensitivity of development location to expected profitability for floorspace type *u*
r^{u}_{ti}	the rent for a unit of floorspace type *u* in zone *i* at time *t*
c^{du}_{pi}	is the cost of developing (*d, u*) at *i* in the present period *p* (in the same units as rents).

A.5.5 The program then checks that the constraints on development are satisfied, ie that

$$F(N)^{du}_{pi} \leq F(P)^{du}_{pi}$$

A.5.6 Any development in excess of the constraint is subtracted, so that the constraint is just satisfied, and excess development is reallocated using a revised version of the same equation in which the terms $F(P)^{du}_{pi}$ are the **remaining** amount of permissible development.

Area total development, density-led calculations

A.5.7 We first find the (unconstrained) "area requirement" for floorspace

$$F(UAR)^{u}_{pj} = \eta^{u}_{p}. \sum_{v \in Occ(u)} \left[X^{v}_{tj} . s^{v}_{j} \right]$$

where

$F(UAR)^{u}_{pj}$	is the unconstrained "area requirement" at period *p* for additional floorspace type *u* in area *j*;
$Occ(u)$	is the set of activities *v* that can occupy floorspace type *u* (note that this is all the activities permitted to occupy *u*, not expected occupiers);
X^{v}_{tj}	is the quantity of activity *v* located in area *j* at time *t*; and
s^{v}_{j}	is the (input) requirement of floorspace activity *v* in area *j*
η^{u}_{p}	is a scalar defining the "area requirement" for floorspace relative to the most recent amount of activity times the input density (this scalar is used to adjust for the fact that there is a timelag between the calculation of the required floorspace and its delivery).

A.5.8 We test whether this is greater than the existing stock plus any development resulting from the FMA-wide process ie whether

$$F(UAR)^{u}_{pj} > \left(F^{u}_{tj} + F(N)^{u}_{pj} \right)$$

where

F_{tj}^{u} is the stock of floorspace type *u* in area *j* at time *t*

$F(N)_{pj}^{u}$ is the quantity of floorspace type *u* to be built in area *j* starting in period *p* resulting from the FMA-wide development model (above).

A.5.9 If so, then the “local” development is a proportion of this shortfall:

$$F(UA)_{pj}^{u} = \alpha_{p}^{u}\left[F(UAR)_{pj}^{u} - \left(F_{tj}^{u} - F(N)_{pj}^{u}\right)\right]$$

where

$F(UA)_{pj}^{u}$ is the unconstrained amount of development of floorspace type *u* in area *j* started in period *p* by the “area model”

α_{p}^{u} is a parameter scaling the whole equation in area *j* (the proportion of the local requirement that will be built).

Distribution of area total development (density-led)

A.5.10 This is done in the same way as for the distribution of FMA-wide total development, but:

- using only the remaining permissible development quantities
- for each area separately
- with separately-input gamma coefficients

A.6 Household formations, transitions and dissolutions

A.6.1 The calculation of household formations is a simple multiplication and summation:

$$H(N)_{pi}^{k} = \sum_{h} H_{ti}^{h} \cdot n_{p}^{hk}$$

where

$H(N)_{pi}^{k}$ is the number of newly-formed households of type *k* formed from the existing households in zone *i* during period *p* (note that the newly-formed households will not necessarily locate in *i*)

H_{ti}^{h} is the number of households of type *h* living in zone *i* at time *t* (the beginning of period *p*)

n_{p}^{hk} is the rate during period *p* at which households of type *k* are formed from households of type *h*

A.6.2 Similar formulae are used for the other changes.

A.6.3 Newly-formed households are accumulated as a “pool” of households to be located in the area where they have been formed – unless they migrate first (see below).

A.6.4 Households which transition from one type to another may be added to that “pool”, or may be treated as “mobile” (“may move”), according to the inputs to MT12. “Mobile” households are also, like “pool” households, potential migrants.

A.7 Migration to and from the Modelled Area

Migration to/from Rest of World modelled in MT12

A.7.1 If migration to and from the Modelled Area is calculated in MT12, then out-migration is calculated as a simple proportion of the households of each type in each zone, using an equation similar to that for household transitions. In-migration for each household type is then calculated as a multiple of the corresponding out-migration. The in-migrant households are totalled by area for location as “pool” households in the household location model.

Migration to/from Rest of World modelled in MM12 – fixed rates

A.7.2 If migration to and from the Modelled Area is calculated in MM12, and fixed ratios are used, then out-migration is calculated in the same way as for MT12 except that:

- the departure rates may vary by area as well as by household type (and year)
- the total number of households leaving an area by migration (out of the Modelled Area, or to elsewhere within the Modelled Area) is constrained to 95% of the pool and mobile households, irrespective of the corresponding level of in-migration

A.7.3 In this case:

- in-migration is also calculated as a multiple of the initial number of households in each area (like out-migration)
- the calculations are done at area level; households that have migrated are only subtracted from the zonal data at the start of the calculations in ML12

A.7.4 Note that if the fixed rates of migration vary between areas, this version of the migration model can result in the total numbers of household changing as a result of relocations within the Modelled Area (eg if households tend to move from a low-out-migration area to a high-out-migration area).

A.8 Migration within the Modelled Area

A.8.1 The within-Modelled Area migration model is of the form

$$M(U)^{hs}_{paz} = H^{h}_{ta}.v(O)^{hs}_{pa}.d^{hs}_{paz}.H^{h}_{tz}.v(D)^{hs}_{pz}.s^{hs}_{p}$$

where

$M(U)^{hs}_{paz}$ is the migration of households type *h* in stream *s* from origin area *a* to destination area *z* during period *p* (before considering constraints);

H^{h}_{ta} is the total number of households of type *h* in area *a* at time *t*;

$v(O)^{hs}_{pa}$ is the origin area *a* push factor for stream *s* migration of households *h* in period *p*, calculated from other variables;

d^{hs}_{paz} is the deterrence effect of distance from *a* to *z* for stream *s* migration of households *h* in period *p*;

H^{h}_{tz} is the total number of households of type *h* in area *z* at time *t*;

$v(D)^{hs}_{pz}$	is the destination area *z* pull factor for stream *s* migration of households *h* in period *p*, calculated from other variables; and
s^{hs}_{p}	is a scaling factor for overall level of migration of households *h* in period *p*.

A.9 Employment growth and decline

A.9.1 The treatment of employment is such that:

- in a Base Case test the growth of employment by sector and area is controlled to match the chosen scenario (eg NTEM), whilst
- in an Alternative Case test the growth of employment by sector and area can pivot about the Base Case, depending on changes in the space and transport systems.

A.9.2 Note that a Reference Case test is not necessarily a Base Case.

A.9.3 In a Base Case run the model simply applies the given growth (or decline) rate to the previous employment by sector and area:

$$g^{s}_{pa} = r^{s}_{pa}$$

where

g^{s}_{pa}	growth factor for sector *s* in period *p* and area *a*
r^{s}_{pa}	an input normal or “reference” growth factor for sector *s* in period *p* and area *a*.

A.9.4 In an Alternative Case run of the model, the growth rates are adjusted.

A.9.5 For “traded” sectors the adjustment depends on whether the Alternative Case improves upon the Base Case in costs of space and in accessibility:

$$g^{s}_{pa} = r^{s}_{pa} \cdot \left(\frac{c^{s}_{ta}}{c^{s}_{[BASE]ta}}\right)^{\beta(c)^{s}_{pa}} \cdot \left(\frac{A^{s}_{ta}}{A^{s}_{[BASE]ta}}\right)^{\beta(A)^{s}_{pa}}$$

where

c^{s}_{ta}	is the cost of space for sector *s* at time *t* in area *a*, in the current (Alternative Case) run, averaged from the results of the location model;
$c^{s}_{[BASE]ta}$	is the corresponding cost in the Base Case;
A^{s}_{ta}	is the accessibility (in cost units) of area *a* for sector *s* at time *t*,in the current (Alternative Case) run;
$A^{s}_{[BASE]ta}$	is the corresponding accessibility in the Base Case;
$\beta(c)^{s}_{pa}$, $\beta(A)^{s}_{pa}$	are the elasticities of growth with respect to cost and accessibility respectively, for sector *s*.

A.9.6 For “non-traded” sectors

$$E^{s}_{(t+1)a} = E^{sB}_{(t+1)a} \;+\; \varsigma^{Ys}_{p}.\left[Y^{A}_{ta} - Y^{B}_{ta}\right] \;+\; \sum_{X} \varsigma^{Xs}_{p}.\left[P^{XA}_{ta} - P^{XB}_{ta}\right]$$

where:

$E^{sB}_{(t+1)a}$	is the employment in sector *s* and area *a* as returned from the base test
Y^{B}_{ta}	is the total household income in the base test in area *a*
Y^{A}_{ta}	is the total household income in the alternative test in area *a*
P^{XB}_{ta}	is the number of residents of type X in area *a* in the base test
P^{XA}_{ta}	is the number of residents of type X in area *a* in the alternative test
ς^{Ys}_{p}	the number of jobs gained or lost per unit increase in Y
ς^{Xs}_{p}	the number of jobs gained or lost per unit increase in X
X	are the different types of residents, ie children, workers, non-workers and retired persons.

A.10 Car ownership

A.10.1 The model works in terms of the probability p1+ that a household owns one or more cars.

A.10.2 The new probability of car ownership is calculated as a function of the previous car ownership and of the changes in licence, income, accessibility, ownership costs, number of workers per households, and running costs.

$$p^{h}_{(t+1)i(1+)} = \frac{s^{h}_{i(1+)}}{1 + \left[\dfrac{s^{h}_{i(1+)} - p^{h}_{ti(1+)}}{p^{h}_{ti(1+)}}\right] \exp\left(-\Delta X^{h}_{pi(1+)}\right)},$$

where

$p^{h}_{(t+1)ic}$	are the updated probabilities of car ownership for households type *h* living in zone *i*
	c = 1+ refers to the probability of owning one or more cars
$s^{h}_{i(1+)}$	is a saturation level of car ownership for household type *h* in zone *i*
p^{h}_{tic}	is the probability of car ownership at the end of the previous time period
$\Delta X^{h}_{pi(1+)}$	is the change in a linear predictor for car-ownership in zone *i* in the current time period.

A.10.3 These formulae are expressed entirely in terms of the previous level of car ownership, the changes in the independent variables and the coefficients.

A.10.4 MC12 calculates the probabilities in the forms shown above, and then converts the results back into the simple proportions of households owning 0, 1, etc cars. Car availability is then calculated from the average number of cars and the average number of adults per household in each household type in each zone.

A.10.5 Note that the car ownership and car availability modelling works entirely in terms of the proportions of households by type and zone in each car ownership or car availability category. The absolute numbers of household by car ownership are not defined until the household location calculations are complete.

A.11 Household location and relocation

A.11.1 The process of locating households includes a calculation of 'pool' households and 'mobile' households. The 'pool' households are those that do not have a previous location (i.e. they are newly formed households or new in-migrants to the area), the 'mobile' households are those with a previous location within the area. It follows that the 'pool' households have to be located whilst the 'mobile' households may be relocated.

A.11.2 The pool households are located by the formula:

$$H(LP)^h_{pi} = \sum_a \left\{ H(P)^h_{pa} \cdot \frac{H(XA)^h_{pi} \cdot \exp(\Delta V^h_{pi})}{\sum_i H(XA)^h_{pi} \cdot \exp(\Delta V^h_{pi})} \right\}$$

where

$H(LP)^h_{pi}$	are the "pool" households of type *h* locating at *i* in period *p*;
$H(P)^h_{pa}$	are the "pool" of households type *h* to be located in area *a* in period *p* (resulting from the transition and migration model);
$H(XA)^h_{pi}$	is the expected number of households of zone *i* in available housing (new, vacant or vacated-by-mobile-households) during period *p* in zone *i*;
ΔV^h_{pi}	is the change in utility of location of zone *i* influencing households type *h* locating in period *p*.

A.11.3 The number of located "mobile" households is found by summing the matrix of moves arriving, i.e.

$$H(LM)^h_{pi} = \sum_o H(LMR)^h_{poi}$$

where

$H(LM)^h_{pi}$	is the mobile households type h located to zone i in the period *p*;
$H(LMR)^h_{poi}$	is the mobile households type h relocated from zone o to zone i.

A.11.4 Note that the relocation process is written in terms of moves from o to i.The numbers of moves are found by

$$H(LMR)^h_{poi} = H(M)^h_{po} \left\{ \frac{H(XA)^h_{pi} . \exp(\Delta V^h_{pi}) . d^h_{poi}}{\sum_i H(XA)^h_{pi} . \exp(\Delta V^h_{pi}) . d^h_{poi}} \right\}$$

where

$H(LMR)^{h}_{poi}$	is the number of mobile households type h relocated from zone o to zone i;
$H(XA)^{h}_{pi}$	is the number of households type h in zone i "expected" to locate in period p (calculated from floorspace and floorspace changes);
ΔV^{h}_{pi}	is the change in utility of location influencing households of type h locating in zone i during period p (the same value as for pool households);
d^{h}_{poi}	is a deterrence function for households type h relocating from o to i in period p.

A.11.5 The cost of location is simply the rent multiplied by the space per unit activity:

$$c^{h}_{pi} = a^{hH}_{pi} . r^{H}_{pi}$$

A.11.6 The change in utility of location is

$$\Delta V^{h}_{pi} = \theta^{hC}_{p} (c^{h}_{pi} - c^{h}_{(tB(U,h))i}) + \theta^{hA}_{p} (A^{h}_{(tA(A,h))i} - A^{h}_{(tB(A,h))i}) + \theta^{hQ}_{p} (Q^{h}_{(tA(Q,h))i} - Q^{h}_{(tB(Q,h))i}) + \theta^{hR}_{p} (R^{h}_{(tA(R,h))i} - R^{h}_{(tB(R,h))i}) + \theta^{hH}_{p} (a^{hH}_{pi} - a^{hH}_{(tB(U,h))i})$$

A.11.7 Ignoring for a moment the more complex time subscripts, the variables on the RHS are:

c^{h}_{pi}	the cost of location for a household of type *h* choosing to locate in zone *i* in period *p* (see below);
A^{h}_{ti}	the accessibility of zone *i* for a household of type *h* at time *t*;
Q^{h}_{ti}	the quality of zone *i* for a household of type *h* at time *t* (i.e. the quality of housing);
R^{h}_{ti}	the environmental quality of zone *i* for a household of type *h* at time *t*;
a^{hH}_{pi}	the floorspace per household which will be occupied by a household of type *h* choosing to locate in zone *i* in period *p* (see below).

A.11.8 The time subscripts are as follows:

p	is the current time period;
t	is the immediate previous year (i.e. data from the database at the beginning of the current period *p*);
tA(U,h)	is the "after" year applicable to variable *U* for household type *h*, and likewise for other variables;
tB(U,h)	is the "before" year applicable to variable *U* for household type *h*, and likewise for other variables.

A.11.9 The timelags are inputs to the model definition, but for the model to work at all there must be zero "after" lags on the cost and floorspace/household variables – otherwise the model will not respond correctly to the iteration of the rent calculations.

A.11.10 The **cost of location** is the rent multiplied by the space per unit activity:

$$c_{pi}^{h} = a_{pi}^{hH} \, .r_{pi}^{H}$$

where the space per household is in turn calculated by

$$a_{pi}^{hH} = q_{i}^{hH} \left[\; b_{p}^{hH} + \frac{\alpha_{p}^{hH} \, (y_{p}^{h} - b_{p}^{hH} \cdot r_{pi}^{H} - b_{p}^{hO} - c_{pi}^{hC} \,)}{r_{pi}^{H}} \; \right]$$

where

y_{p}^{h}	income of households type h during period p (defined in ML12<><>.inp, block LCML01);
r_{pi}^{H}	rent per unit of housing floorspace;
b_{p}^{hH}	is the minimum **H**ousing floorspace per household type *h* locating in period *p* (so $(b_{p}^{hH} \cdot r_{pi}^{H})$ is the rent of the minimum amount of housing floorspace);
b_{p}^{hO}	is the minimum expenditure of a household type *h* on **O**ther goods and services in period *p*;
α_{p}^{hH}	is the proportion of discretionary income that a household type *h* locating in period *p* will spend on **H**ousing (where discretionary income is the term in (brackets) ie total income minus expenditure on minimal housing floorspace, other goods and services and car ownership);
q_{i}^{hH}	is an adjustment factor, calculated to reconcile households, floorspace and rents in the base year
c_{pi}^{hC}	is the (minimal) cost of car ownership per household (based on the level of car ownership and the input (minimal) cost of car ownership)

A.11.11 In words, the space per household is their minimum requirement plus the space they can occupy, at the prevailing rent, by spending their discretionary income – all adjusted by the *q* factor which is calculated in the base year to reconcile households, floorspace and rents.

A.11.12 The **distance-deterrence function** is a negative logistic function:

$$d_{poi}^{h} = \frac{\alpha_{p}^{h} + \exp(\beta_{p}^{h}.D_{oi} + k_{p}^{h})}{1 + \exp(\beta_{p}^{h}.D_{oi} + k_{p}^{h})}$$

where

D_{oi}	the distance from o to i;
$\alpha_{p}^{h} \;\; \beta_{p}^{h} \;\; k_{p}^{h}$	coefficients of the distance deterrence function for households type h in period p.

A.12 Employment location

A.12.1 There is in effect a separate location/property market model for each floorspace type and for the employment activities that occupy that type of floorspace; there are no direct interactions between these location/property market models when they run in any one year.

A.12.2 The majority of employment location is a distribution of the "pool" of jobs of one activity to be located to the zones of one area in one year. Some employment is also redistributed from its initial location. Pool employment of employment activity *s* is located by:

$$E(LP)^s_{p(i\in a)} = E(P)^s_{pa} \cdot \frac{E^s_{ti} \cdot \left(\dfrac{F(A)^u_{pi}}{F(O)^u_{ti}}\right) \cdot \exp(\Delta V^s_{pi})}{\sum_{i\in a}\left\{E^s_{ti} \cdot \left(\dfrac{F(A)^u_{pi}}{F(O)^u_{ti}}\right) \cdot \exp(\Delta V^s_{pi})\right\}}$$

and "mobile" activities are located by:

$$E(LM)^s_{p(i\in a)} = \left[\sum_{i\in a} E(M)^s_{pi}\right] \cdot \left\{\frac{E(M)^s_{pi} \cdot \left(\dfrac{F(A)^u_{pi}}{F(M)^u_{pi}}\right) \cdot \exp(\Delta V^s_{pi})}{\sum_{i\in a}\left[E(M)^s_{pi} \cdot \left(\dfrac{F(A)^u_{pi}}{F(M)^u_{pi}}\right) \cdot \exp(\Delta V^s_{pi})\right]}\right\}$$

where

$E(LP)^s_{pi}$ is the employment sector s located from the pool to zone i;

$E(P)^s_{pa}$ is the area "pool" of employment in sector s, to be located;

$E(LM)^s_{pi}$ is mobile employment in sector s located to zone i;

$E(M)^s_{pi}$ is mobile employment in sector s initially located in zone i;

$F(A)^u_{pi}$ is available floorspace type u within which s can locate;

$F(O)^u_{ti}$ is previous occupied floorspace of type u; and

$F(M)^u_{pi}$ is space of type u previously occupied by employment (of any sector) now classified as "mobile".

A.12.3 In both cases, changes in distribution (compared with the previous distribution) tend to be strongly influenced by changes in the quantity of floorspace which landlords make available (which in general will vary as the rent changes) and rather less strongly by a utility term reflecting changes in cost and accessibility. The utility term is calculated as

$$\Delta V^{s}_{pi} = \theta^{sC}_{p} \left(c^{s}_{pi} - c^{s}_{(tB(U,s))i} \right) \quad + \theta^{sA}_{p} \left(A^{s}_{(tA(A,s))i} - A^{s}_{(tB(A,s))i} \right)$$

A.12.4 The timelags here work in the same way as for households, and again the variables *c* and *A* are cost of location and accessibility respectively. The cost of location is calculated as the space occupied per employee times the cost per unit of floorspace:

$$c^{s}_{pi} = a^{su}_{pi} \cdot c(L)^{s}_{pi}$$

A.12.5 The cost of location per unit floorspace is calculated as

$$c(L)^{s}_{pi} = r^{u}_{pi} \left(1 + \xi^{s}_{pi} + f^{s}_{p} \right) + g^{s}_{pi} + h^{s}_{p}$$

where

ξ^{s}_{pi}	is property tax for activity *s* as a proportion of rent;
f^{s}_{p}	is other floorspace costs for activity *s* as a proportion of rent;
g^{s}_{pi}	is fixed property tax for activity *s*;
h^{s}_{p}	is fixed other floorspace costs for activity *s*.

A.12.6 Floorspace per unit activity is found as

$$a^{su}_{pi} = a(\min)^{su}_{p} + \phi^{s}_{p} \cdot \left(a^{su}_{(p-1)i} - a(\min)^{su}_{p} \right) \cdot \left(\frac{c(L)^{s}_{pi}}{c(L)^{s}_{(p-1)i}} \right)^{\gamma^{s}}$$

where

a^{su}_{pi}	units of floorspace type *u* occupied per worker in employment activity *s* in zone *i* at time *t+1*;
$a(\min)^{su}_{p}$	minimum floorspace type *u* per worker in employment activity *s* locating in period *p*;
φ^{s}_{p}	(phi) proportional increase in the variable amount of space per job in activity *s* during period *p* (if rents remain constant);
$c(L)^{s}_{pi}$	is the cost per unit floorspace for locating activity *s* in zone *i* during period *p*;
γ^{s}	elasticity of floorspace per employee with respect to rent per unit space.

A.12.7 Note that (like the rest of the location model) the increase factor φ^{s}_{p} applies only to mobile or pool employment; it does not affect the demand for space from immobile employment.

A.13 Converting jobs by activity to jobs by socio-economic level

A.13.1 In models that do not use the full Regional Economic Model (but may have variable employment scenarios), the conversion of jobs by activity to jobs by activity and socio-economic level involves the following steps:

- first, the model converts jobs by activity to jobs by activity and socio-economic level, for each zone and each employment activity, using the mixture of socio-economic levels for that zone and activity in the preceding database
- these zonal results are then adjusted so that the target mixture of SELs within each activity is matched overall

A.13.2 The targets may be input explicitly in the inputs to ME12. If no inputs are provided, the program will use the mixture of SELs by activity in the previous database as implicit targets.

A.13.3 The control to match the overall mixture of SELs within each activity to the targets is applied across the whole of the Modelled Area. It ensures that providing a lot more floorspace in a zone which has (for example) a particularly low proportion of skilled workers in the relevant activities cannot reduce the model average proportions of skilled workers for those activities.

A.14 Employment status adjustment and commuting

A.14.1 Having converted jobs by activity to jobs by SEL as described above, the ME12 program goes through the following steps.

Steps in employment status adjustment and commuting

Step	Operation
1	Set up initial supply of workers by zone (both actual [by household seg] and notional [by worker SEL]) given results of preceding models, and the corresponding maxima
2	Scale the travel-to-work (TTW) matrices by the change in the notional supply (compared with the previous database) by home zone, worker SEL and car-ownership
3	Scale the travel-to-work (TTW) matrices again to match the new demand for labour by work zone and worker SEL
4	If the supply of labour (TTW from one home zone) is greater than the notional supply (by car-ownership and worker SEL), scale down the associated TTW flows until their total equals the notional supply. *If no scaling down is required go to Step 7.*
5	*If adjustments to the TTW matrices were made at Step 4*, adjust households' employment status (workers per household) to match the reduced labour supply in the TTW matrices
6	*If adjustments to the TTW matrices were made at Step 4,* then some jobs are currently unfilled by the TTW matrices: scale the TTW matrices upwards in proportion to the unused labour in each home zone, worker SEL and car-ownership level until all jobs are filled.
7	Adjust households' employment status to match the increased labour supply in the TTW matrices (the opposite of Step 5, to respond to the increases in Step 3 or Step 6).
8	Check that totals of the TTW matrices by home zone match the labour supply (regardless of seg) and that the totals of the TTW matrices by work zone and worker SEL match the labour demand. If necessary, reiterate.

A.15 Other persons in households

A.15.1 For each modelled zone, the numbers of non-working working-age adults are found by adding the minimum numbers of non-workers in the resident household of each type to the numbers of potential workers not in work (from the calculations above) in those households.

A.15.2 Numbers of children and retired persons in the households of each type in each zone are found first by applying the zonal ratios of such persons per household of each type, then controlling to input target values for the overall ratios. This ensures that (for example) zones with larger-than-average numbers of children per household-with-children will tend to retain that characteristic over time, but that the ratio is changed so that the overall results conform to the demographic scenario.

A.16 Floorspace quality

A.16.1 The quality model works only on housing. The model proper works in two steps:

- first, it calculates the quality of housing which would eventually come about in each zone given the average income of households in the zone
- secondly, it calculates the new value of the quality variable by moving the current quality a specified proportion of the way towards that eventual quality

A.16.2 Mathematically, therefore, it calculates the asymptote towards which the quality variable will move, in the absence of any other changes, and adjusts the quality a given fraction of the distance towards that asymptote.

A.16.3 The first step is

$$Q(E)^s_{pi} = \alpha^s_p + \beta^s_p \cdot \bar{y}_{ti}$$

where

$Q(E)^s_{pi}$	is the "eventual" quality to which floorspace type *s* in zone *i* would move;
$\bar{y}_{ti}$	is the average income of households in zone *i* in the preceding database;
α^s_p, β^s_p	are coefficients.

A.16.4 The second step is

$$Q^s_{(t+1)i} = Q(D)^s_{pi} \cdot \left(1 - f^s_p\right) + Q(E)^s_{pi} \cdot f^s_p$$

where

$Q^s_{(t+1)i}$	is the quality of floorspace type *s* in zone *i* at the end of the present period, ie at time *(t+1)*;
$Q(D)^s_{pi}$	is the quality of the floorspace type *s* in zone *i* after the operations of the development model in the present period *p*, ie after adjustment for the quality of new floorspace;
f^s_p	is the rate of adjustment, as a fraction between 0 and 1.

[end]