TELMOS14 LUTI MODELLING

Model Development Report: Fixed Scenario Model

Prepared for Transport Scotland

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Footnotes are used in the conventional way in the text, and are identified by ordinary numerals. Endnotes are identified by Roman numerals and are used as part of DSC's QA arrangements, to provide detailed tracking of particular inputs.

This report has been prepared by David Simmonds Consultancy Limited for Transport Scotland. Opinions expressed in the report are not necessarily those of Transport Scotland.

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ABBREVIATIONS

Abbreviation	Meaning
APPI	Assembly of Planning Policy Inputs
BRES	Business Register and Employment Survey
DfT	Department for Transport
DSC	David Simmonds Consultancy
FMA	Fully Modelled Area
GIS	Geographical Information System
GMPTE	Greater Manchester Passenger Transport Executive
GMSPM	Greater Manchester Strategy Planning Model
GVA	Gross Value Added
HRP	Household Representative Person (2011 Census terminology)
LATIS	Land Use and Transport Integrated in Scotland
LUTI	land-use/transport interaction
NRS	National Records of Scotland
ONS	Office for National Statistics
REM	Regional Economic Model
RPI	Retail Price Index
SEL	Socio-economic Level
SIAS	LATIS Lot 1 Transport Consultants
SIC	Standard Industrial Classification
SOC	Standard Occupational Classification
TELMoS	Transport and Economic/Land Use Model of Scotland
TMfS	Transport Model for Scotland
UKCES	United Kingdom Commission for Employment and Skills

1 INTRODUCTION

1.1 Background and scope

1.1.1 This Report has been prepared by David Simmonds Consultancy Ltd (DSC) for Transport Scotland. It has been prepared under the following task orders:

- A9885015 – model development programme phase 1
- A11724174 – implementation phase 1
- A14372565 – implementation phase 2 (2016/17)

1.1.2 DSC are Lot 3 consultants on the LATIS framework, through which this package of work has been let.

1.1.3 The task orders divided the required work into the following tasks:

- Task 1: detailed model design
- Task 2: 2014 base year database assembly;
- Task 3: creation of inputs for forecast years
- Task 4: creation of new planning policy inputs
- Task 5: Model enhancements
- Task 6: Model Implementation
- Task 7: Creation of Reference Case
- Task 8: Demonstration Tests
- Task 9: Reporting

1.1.4 The current reporting of the LUTI modelling covers the development of the Fixed scenario version of TELMoS14 model. Further reporting of the Reference Case and the Planning Policy Inputs are:

- included within the APPI14 report, which describes the information on planned development provided by the local planning authorities and national park authorities in 2014; and
- to be included within the Model Demonstration Report which describes the Reference Case and Demonstration Tests.

1.1.5 This Model Development Report documents how the model has been built and why it behaves as it does. Hence this document covers

- the general concept of LUTI modelling, including key caveats and limitations;
- the design of the model;
- the preparation of the input database;

- the ways in which scenarios and planning policies are input to the model;
- the coefficients which control the sensitivities of the model results, and how these have been arrived at[1];
- how the planning policy inputs were prepared; and
- the scenario adopted.

1.2 Report structure

1.2.1 The Model Development Report is structured as follows.

1.2.2 Chapter 2 provides an overview of the model and how it has been implemented. It covers the whole of the model development work including the enhancements agreed with Transport Scotland.

1.2.3 The next three chapters document

- the geographical structures used in the modelling: the "zone system" (chapter 3);
- the data which describe the 2014 land-use/economic situation from which the model starts (chapter 4) – these are the variables which the model updates over time; and
- interface to the transport model (chapter 5).

1.2.4 The following two chapters describe the inputs which define and implement

- the economic and demographic scenario (chapter 6);
- the descriptions of planning policy (chapter 7).

1.2.5 These are followed by four chapters on how we have implemented and calibrated the various processes of change in the model, organized in terms of

- accessibility calculations (chapter 8),
- businesses' choices and responses (chapter 9),
- household choices and responses (chapter 10), and
- developers choices and responses (chapter 11).

1.2.6 The Appendices provide

- a mathematical outline of the model (Appendix A);
- detailed figures describing the economic and demographic scenarios (Appendix B);
- tables describing Local Authority planning policy inputs (Appendix C);
- detailed description of viability modelling in the report (Appendix D); and
- reference maps of the zones and macrozones modelled (Appendix F).

[1] A detailed list of coefficients used within the model will be provided in the Appendix E

1.3 Acknowledgements

1.3.1 We are grateful to Transport Scotland and the LATIS Framework Lot 1 Transport Modelling Consultants for their advice and assistance in the development of TELMoS14.

2 OVERVIEW

2.1 Objectives

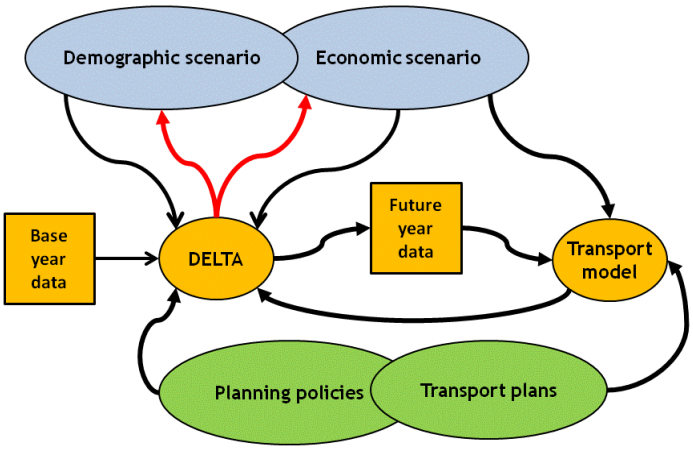
2.1.1 In 2013 DSC were commissioned to prepare a Model Development Programme. This set out a series of model updates and enhancements to TELMoS12 (the then current version of Transport Scotland's land use and economic forecasting model). In parallel, the LATIS Lot 1 Consultants were commissioned to prepare a programme of work to update and refine the Strategic Transport Model, TMfS.

2.1.2 Our Development Programme built upon the previous version of the TELMoS model. As such the new model version is firmly in the tradition of dynamic land-use/transport interaction (LUTI) modelling, i.e. modelling which forecasts in steps through time, and where the central feature of the modelling is to forecast the changing location of households and employment. This tradition is one that has developed from the 1950s to date; the DELTA package was initially developed in the 1990s and has been considerably extended and enhanced since then. Other applications of DELTA have been used for other projects in Scotland and for models in England, France, Italy, New Zealand and South Korea.

2.2 Scope and limitations

2.2.1 The full LUTI approach is illustrated in Figure 2-1. A full model starts from an input base year and forecasts forward over time, alternatively considering land-use/economic and transport changes, predicting the detailed outcomes resulting from the interaction of the "top-down" scenarios of overall growth and the "bottom-up" policies of land-use and transport planning. The impacts of interventions, singly or in combination, are calculated by comparing the results of model runs with and without those interventions. In some cases, the outputs of the model, influenced by policies and plans, may modify the economic and demographic scenarios (the red links in Figure 2-1 – note these imply an adjustment of the input scenario in response to particular plans and policies, they do not make the process circular).

Figure 2-1 Scenarios, policies and models



2.2.2 One of the key issues in LUTI modelling is whether the scenarios are taken strictly as given, or may be modified by the interventions tested (the red arrows in Figure 2-1). The focus of LUTI modelling has generally been on modelling the distribution of fixed totals or economic activity, though models where the total scenarios can change in response to changes in forecast conditions (and hence in response to policy) have been implemented, particularly in models for smaller sub-regions. In the present work for Transport Scotland, the modelling to date has been with fixed total scenarios for Scotland as a whole. This means that the effects of any intervention that we test will be a zero-sum game: if some macrozones gain jobs or residents, then others must lose, and the sum of gains must equal the sum of losses. Work is continuing on a different version of the TELMoS model which is intended to estimate the possible effects interventions on the total level of economic activity in Scotland; this will have the ability to forecast net gains or losses.

2.3 Geographical structure- zone system

2.3.1 The zone system of the model has been created by LATIS Lot 1 transport modelling consultants, SIAS, and there is a one to one match with the TELMoS14 zones used in the land use model. Within TELMoS14 there are 799 zones altogether, of these 783 are fully modelled and 16 are external. The fully modelled area (FMA) zones are mapped for reference in Figure F-1, they cover the whole of Scotland. The external zones cover the rest of Great Britain.

2.3.2 Parts of the model work at a spatially more aggregate level, known in TELMoS14 terminology as macrozones. These are aggregations of the 799 zones. There are, 44 macrozones covering the fully modelled area and 16 the external zones. Within the Fully Modelled Area, these attempt to represent the 2011 based Travel to Work Areas. The FMA macrozones are also mapped for reference in Figure F-2.

2.3.3 The zone system is described in more detail in Chapter 3.

2.4 Base land-use data

2.4.1 The base year for both TELMoS14 and TMfS14 is 2014. The starting land-use database quantifying the 2014 situation was developed using data from the 2011

Census of Population as far as possible, plus data from other sources for variables outside the scope of the Census. Other sources of data have been used to capture change over the period from 2011 to 2014.

2.4.2 An important but not necessarily obvious feature of the model is that it starts from a database representing our observations or estimates of the base year situation, and forecasts a new database containing the same variables, at the same level of detail, for each future year. There can be long time-lags within the model dynamics, but after the first few years, most of the data inputs to the model are themselves the forecasts produced for earlier years.

2.4.3 The database is essentially for the 783 FMA zones. The macrozone database is derived by aggregating from the zonal database. The preparation of the database is documented in Chapter 4.

2.5 Transport data

2.5.1 The transport data input to TELMoS consists of matrices of generalised costs by mode and purpose, for the base year and for all of the transport model forecast years, 2017, 2022, 2027, 2032 and 2037. From the generalised costs data the land use model adjusts accessibility to housing and labour markets. The land use model also passes population, households, and employment data to the transport model in the transport model forecast years using an interface.

2.5.2 The interface between the land use and transport model is described in Chapter 5 and processing of the generalised costs data within the land use model is described in Chapter 8.

2.6 Time horizon and modelled years

2.6.1 The DELTA package is used to implement the TELMoS14 model runs in one year steps. TELMoS14 can currently forecast to 2041. The extension of the forecast period beyond the last transport model year allows the model to capture some (albeit limited) land use impact of that transport forecast.

2.7 Accessibility calculations

2.7.1 The data obtained from TMfS14 is combined with TELMoS14's own data on land-uses to calculate a range of accessibility measures for each zone and macrozone. These are recalculated in each year of each forecast. It is the differences between the accessibilities based on Do-Something generalised costs and those based on Do-Minimum generalised costs that give rise to the different forecasts and hence show the impact of any interventions tested.

2.7.2 The implementation of the accessibility calculations is reported in Chapter 8.

2.8 Business, household and developer processes: choices and responses

2.8.1 Business activity is measured mainly in terms of employment. National growth in employment (and the associated growth in production) is controlled to a given scenario. The present modelling work is concerned with how transport and land use interventions will affect the distribution of economic activity within Scotland, and

does not allow the totals to vary. Within each run of the model, the location of employment is determined through processes which represent business choices about

- where within Scotland to invest;
- where to trade and to produce; and
- at a more local level, about where to locate premises.

2.8.2 Each choice is influenced by accessibility or transport cost terms, as well as by a range of other variables.

2.8.3 The number of households and the size of the population are likewise constrained to a given national scenario. The location and mix of households and residents changes over time through

- migration (longer-distance moves, particularly influenced by employment prospects);
- local moves (particularly influenced by housing availability, but also by accessibility to work and services); and
- gaining or losing employment.

2.8.4 Changes in the location of businesses affect households over time, by changing the demand for labour in each location; and changes in the location of households affect businesses over time, by changing the supply of labour and the demand for services.

2.8.5 Developer choices are represented by models of how much floorspace to build, and where to build it. Developers' decisions are driven by expected profits, which in turn are driven by occupier demand: development therefore tends to follow businesses and households, whilst also being constrained by the inputs representing planning policy (which control the amount of building which can take place in any location at any time).

2.8.6 The sensitivities of businesses, households and developers to different stimuli are set mainly by adjusting the model so as to reproduce, as far as practical and appropriate, elasticities or other measures of response which have been drawn from previous research. Details of the research used are given in the text and in the appendices. Note that this approach means that most of the calibration of the model is done by repeatedly running the model itself, measuring and adjusting its response to a variety of hypothetical changes.

2.8.7 The calibration of the model is described in Chapters 9 to 11.

2.9 Developer responses and planning policy inputs

2.9.1 The modelling of developer responses and the preparation of the planning policy inputs are reported in Chapter 7 and Chapter 11.

3 TELMOS14 ZONE SYSTEM

3.1 Starting point: TELMoS12 zones

3.1.1 The previous version of the Transport and Economic Land-Use Model of Scotland, TELMoS12, modelled land use change across all of Scotland. This model comprised of a zone system with 720 zones. Of these, 712 covered mainland Scotland and the islands, 8 were external zones covering the rest of Great Britain.

3.1.2 The TELMoS12 zone geography was based upon the 2001 Census Datazone geography and was created by the LATIS Transport Modelling Consultants, SIAS.

3.2 TELMoS14 zone system

3.2.1 The TELMoS14 zones have been defined by the Lot 1 Transport Modelling Consultants as part of the development of TMfS14.

3.2.2 They are based on the previous TELMoS12 zone system and have been updated to take into account changes from the 2001 Census Datazone geography to the most recent 2011 Datazone geography. In some instances, 2011 datazone boundaries differ from the 2001 datazone boundaries. As a result, the boundaries of the TELMoS12 and TELMoS14 zone sets differ for some zones even where no change was considered necessary.

3.2.3 The TELMoS14 zone system is comprised of 799 zones. Of these 783 cover the mainland and islands of Scotland. The other 16 are external zones that cover the rest of Great Britain.

3.3 Additional zones in TELMoS14

3.3.1 The additional zones in the TELMoS14 system result from the disaggregation of some TELMoS12 zones. These are mainly due to the enhanced modelling requirements of both the Transport and Land Use models.

3.3.2 The enhancements include:

- disaggregation of zones along the Perth-Inverness corridor to better inform the modelling of the A9 highway improvements;
- disaggregation of zones along the Aberdeen-Inverness corridor to better inform modelling of the A96 improvements;
- applying a maxim of only one railway station present per zone;
- disaggregation of some of the island zones, to better represent ferry movements to the islands of Muck, Eigg, Rum and Canna were split away from the Mainland; and

- the key Ports of Cairnryan, Greenock, Grangemouth, Rosyth and Aberdeen were included as individual zones.

3.3.3 There has been further disaggregation of the TELMoS12 zones, within the rest of Great Britain. This was to facilitate better modelling of cross-border interactions. The zones outside Scotland are based upon aggregations of the 2011 Travel to Work Areas, and include separation of Carlisle as an individual zone.

3.3.4 A map of the TELMoS14 FMA zones is included in Figure F-1 in Appendix F

3.4 TELMoS14 macrozones

3.4.1 Macrozones are larger strategic areas that are intended, in TELMoS, to represent labour market areas. Macrozones are defined as groups of zones and in TELMoS14 are based as far as possible on the 2011 based Travel to Work Areas.

3.4.2 In TELMoS14 there are 44 macrozones covering Scotland and 16 covering the rest of Great Britain. A map of the TELMoS14 FMA macrozones is included Figure F-2 in Appendix F.

3.4.3 The macrozone system is used within the migration and economic components of the land-use model. It is invisible to the transport model (and, for many purposes, invisible to the user of model results).

4 LAND-USE/ECONOMIC DATABASE

4.1 Overview

4.1.1 This chapter describes the development of the 2014 base year land-use/economic database which the model takes as the given starting point from which to forecast forward over time.

4.1.2 Note that in TELMoS14 terminology, the word "activities" is used as a generic term covering both the different categories of employment identified at zonal level in the model, the different categories of households (e.g. single, two-plus adults etc.) and the different categories of persons not in households.

4.1.3 The TELMoS14 model forecast households, population and employment at TELMoS zonal level for each year starting from 2014.

4.2 Employment database

4.2.1 The TELMoS14 employment database is based on specially commissioned Census output from the 2011 Census. The key data used in processing of the TELMoS14 employment activity database is 2011 Census workplace employment data: Table WU06BUK_msoa- 'Location of usual residence and place of work by industry'.

4.2.2 Table WU06BUK contains employment data[2] by broad industrial category (SIC 2007) in 2001 Intermediate Zones[3]. The total number of jobs in commissioned table WU06BUK is consistent with the data on people aged 16 and over in employment by place of residence and industry from the 2011 Census Table AT_012_2011[4].

4.2.3 The employment data provided in table WU06BUK used 2001 Intermediate zones. The first task in processing the data for input to the Land Use model was to convert the data from 2001 Intermediate zone geography to 2011 Intermediate zone geography.

4.2.4 At the time of processing neither the National Records of Scotland (NRS) or the Office for National Statistics (ONS) had published a look-up table between the different geographies. A look up table between the 2001 and 2011 geographies was created using GIS techniques.

4.2.5 More detailed representation of employment activities was introduced in this version of TELMoS to:

[2] Employment data represents total jobs that we assume to be equal to total workers.

[3] Intermediate zones are clusters of datazones that sit within local authority areas.

[4] http://www.scotlandscensus.gov.uk/documents/additional_tables/AT_012_2011.xls

- improve the modelling of resident workers who do not have a fixed place of work or work from home. These resident workers' homes are assumed to be their workplace; they are not modelled as working in commercial floorspace (in Table 4-2 these are described as QW or quasi-workers). 16 additional employment activities have been introduced, one for those who work at home, for each economic sector;
- better represent the Energy Sector by disaggregating into three separate sectors: oil and gas sector; coal and lignite; and other extraction and mining. This disaggregation was in response to concerns raised with the approach to economic modelling of the energy sector in TELMoS12 (where energy was treated as one). Disaggregation of energy in to three separate activities allows better representation of the spatial patterns of employment of those working in Energy across Scotland. Within TELMoS14's economic scenario (see Section 6) oil and gas sector jobs are only located in Aberdeen, Aberdeenshire and Shetland, coal and lignite are placed in East Ayrshire, any other jobs in oil and Mining sector are stone quarrying related;
- disaggregate business services into the nine separate activities (activities 61 to 69). The objective in doing so was to distinguish services that are fairly uniformly dispersed, and which can be assumed to serve relatively local markets, from that which are more concentrated and likely to serve non-local (national or international) markets. The different geographical macrozones over which these types of services operate will affect their sensitivity to transport change;
- disaggregate retail into two separate activities (activities 55 and 56). We have assumed that 90% of retailing within the major retail centres is "non-local" and the remaining 10% is "local". It is assumed that the retail centres will attract people from across the region and beyond.
- disaggregate public administration into two separate activities (activities 70 and 71) based on the proportions of Local and Non-Local Authority employment.

4.2.6 A critical input to the business services disaggregation was ONS work on the spatial concentration or dispersion of industries. This provided a ready-made categorisation of services into highly dispersed, moderately dispersed, moderately concentrated and highly concentrated[5].

4.2.7 Additionally, we used data from the Business Register and Employment Survey (BRES) to disaggregate broad industrial categories in Table WU06BUK to more detailed economic activities used in TELMoS14.

4.2.8 Employment activities were further disaggregated by socio-economic level (SEL). The split by SEL was informed by 2011 Scottish Census table DC6604SC 'Occupation by Industry', which provides the number of workers by industry and occupation for each local authority. Correspondence between socio-economic levels

[5] www.ons.gov.uk/ons/rel/regional-trends/regional-economic-analysis/the-spatial-distribution-of-industries/indices-table.xls

applied in TELMoS14 and standard occupational classifications (2010) are provided in Table 4-1.

Table 4-1 Socio-economic levels and Standard Occupational Classification correspondence

Socio-Economic Level (SEL)	Standard Occupational Classification (2010)	
1. Professional and managerial occupations	1	Managers and senior Officials
	2	Professional Occupations
2. Other non-manual occupations	3	Associate Professional and Technical Occupations
	4	Administrative and Secretarial Occupations
3. Skilled trades, sales and service occupations	5	Skilled Trade Occupations
	6	Personal Service Occupations
	7	Sales and Customer Service Occupations
4. Less skilled and elementary occupations	8	Process, Plant and Machine Operatives
	9	Elementary Occupations

4.2.9 The processing of the Census material created an interim 2011 database of employment activity, zone, and SEL. The final step involved moving from a 2011 to 2014 based database. BRES and UKCES Labour market projections[6] data were used to move the TELMoS employment database from a 2011 to 2014 base.

4.2.10 The resulting TELMoS14 employment activities and SIC (2007) correspondence are shown in Table 4-2.

Table 4-2 TELMoS14 Employment Activities and SIC (2007) correspondence

Activity	Activity Description	Standard Industrial Classification 2007 categories (Census 2011 WP605)
41	Agriculture, forestry and fishing (non-manual)	A Agriculture, forestry and fishing
42	Agriculture, forestry and fishing (manual)	A Agriculture, forestry and fishing
43	Coal and lignite (manual)	B 05 Mining of coal and lignite
44	Coal and lignite (non-manual)	B 05 Mining of coal and lignite
45	oil and gas (manual)	B 06 Extraction of crude petroleum and natural gas
46	oil and gas (non-manual)	B 06 Extraction of crude petroleum and natural gas
47	Other Extraction & Mining (manual)	B 07 Mining of metal ores; B 08 Other mining and quarrying; B 09 Mining support service activities
48	Other Extraction & Mining (non-manual)	B 07 Mining of metal ores; B 08 Other mining and quarrying; B 09 Mining support service activities
49	Manufacturing (non-manual)	C 10-32 Manufacturing
50	Manufacturing (manual)	C 10-32 Manufacturing

[6] https://www.gov.uk/government/publications/ukces-labour-market-projections-for-scotland-2014-to-2024

Activity	**Activity Description**	**Standard Industrial Classification 2007 categories (Census 2011 WP605)**
51	Electricity, gas, steam and air conditioning supply	D Electricity, gas, steam and air conditioning supply
52	Water supply; sewerage, waste management and remediation activities	E Water supply, sewage, waste management and remediation activities
53	Construction	F Construction
54	Wholesale and repair of motor vehicles and motorcycles	G Wholesale and retail trade; repair of motor vehicles and motor cycles
55	Retail non Local	G Wholesale and retail trade; repair of motor vehicles and motor cycles
56	Retail Local	G Wholesale and retail trade; repair of motor vehicles and motor cycles
57	Transport	H Transport and storage
58	Storage	H Transport and storage
59	Accommodation and food service activities and ARTS	I Accommodation and food service activities; R and S Arts, entertainment and recreation; other service activities
60	Information and communication	J Information and communication
61	Very specialized services	K Financial and insurance activities
62	Highly concentrated Business Services	L Real estate activities
63	Moderately concentrated Business Services	M Professional, scientific and technical activities
64	Moderately dispersed Business Services	N Administrative and support service activities
65	Highly dispersed Business Services	N Administrative and support service activities
66	Monetary intermediation Non local	K 641 Monetary intermediation
67	Monetary intermediation local	K 641 Monetary intermediation
68	Insurance Non Local	K 651 Insurance
69	Insurance Local	K 651 Insurance
70	Public administration and defence; compulsory social security Local	O Public Administration and defence, compulsory social security
71	Public administration and defence; compulsory social security Non-Local	O Public Administration and defence, compulsory social security
72	Higher Education	P Education
73	other Education	P Education

Activity	**Activity Description**	**Standard Industrial Classification 2007 categories (Census 2011 WP605)**
74	Human health and social work activities	Q Human health and social work activities
75	Other service activities (22, 23, 24) non manual	T Activities of households as employers, undifferentiated goods - and services - producing activities of households for own use; U Activities of extraterritorial organisations and bodies
76	Other service activities (22, 23, 24) manual	T Activities of households as employers, undifferentiated goods - and services - producing activities of households for own use; U Activities of extraterritorial organisations and bodies
77	Agriculture, forestry and fishing (*QW*[7])	A Agriculture, forestry and fishing
78	oil and gas manual (*QW*)	B 05 Mining of coal and lignite
79	Coal and lignite(*QW*)	B 06 Extraction of crude petroleum and natural gas
80	Other Extraction & Mining(*QW*)	B 07 Mining of metal ores, B 08 Other mining and quarrying, B 09 Mining support service activities
81	Manufacturing(*QW*)	C 10-32 Manufacturing
82	energy(*QW*)	D Electricity, gas, steam and air conditioning supply; E Water supply, sewage, waste management and remediation activities
83	Construction(*QW*)	F Construction
84	Wholesale and retail trade; repair of motor vehicles and motorcycles(*QW*)	G Wholesale and retail trade; repair of motor vehicles and motor cycles
85	Transport and storage(*QW*)	H Transport and storage
86	Accommodation and food service activities and ARTS(*QW*)	I Accommodation and food service activities; R and S Arts, entertainment and recreation; other service activities
87	Information and communication(*QW*)	J Information and communication
88	business services(*QW*)	K Financial and insurance activities; L Real estate activities; M Professional, scientific and technical activities; N Administrative and support service activities
89	Public administration and defence; compulsory social security(*QW*)	O Public Administration and defence, compulsory social security
90	other Education(*QW*)	P Education
91	Human health and social work activities(*QW*)	Q Human health and social work activities

[7] Where QW stands for quasi-worker.

Activity	Activity Description	Standard Industrial Classification 2007 categories (Census 2011 WP605)
92	others(*QW*)	T Activities of households as employers; undifferentiated goods - and services - producing activities of households for own use

4.3 Household and population data

4.3.1 Within TELMoS14 households have been classified into nine categories. These are shown in Table 4-3. The household categories are based upon:

- three "life stage" categories: young, older or retired;
- households with and without children; and
- four SELs which are based on groupings of occupations (see Table 4-1).

Table 4-3 TELMoS14 Household Activities

Activities	Household Description
1 - 4	Young Single (under 50) SEL 1-4
5 - 8	Older Single (50-64) - SEL1-4
9 - 12	Retired Single (65+) – SEL1-4
13 - 16	Single Parent with Children - SEL1-4
17 - 20	2 young adults or more no children (under 50) -SEL 1-4
21 - 24	2 older adults or more no children (50-64) - SEL1 - 4
25 - 28	2 adults or more + child -SEL1- 4
29 - 32	2 retired adults or more (65+) - SEL1- 4
33	Student households

4.3.2 Persons in households are classified into four types:

- children
- working
- non-working of working age (most but not all of whom are potential workers)
- retired persons.

4.3.3 Retired households consist wholly of retired persons. Working-age residents are of a defined socio-economic level, but the industry in which they work is not identified in the residential data.

4.3.4 An additional household category was introduced in TELMoS14 to represent student households. The definition is based upon that applied in the 2011 Scottish Census and refers to households where all of the household members are students and unrelated. These households have been included as it is recognized that in some zones they can occupy a sizeable proportion of the residential stock.

4.3.5 Persons not in households (e.g. residents in institutions) are included in the population database for completeness; however the processes of demographic change, relocation and migration are not applied to persons not in households within TELMoS14.

Persons not in households are categorized into Immobile, Mobile, Students and Workers.

4.3.6 A range of information sources was used to assemble this data, including specially commissioned Census output from the 2011 Census as well as the 'standard' census release data obtained from Scotland's Census[8].

4.3.7 The tables commissioned from NRS are:

- Table CT_0093a_2011 - Bespoke household composition by Occupation of HRP by Person type;
- Table CT_0093b_2011 - Bespoke household composition by Occupation of HRP by number of cars or vans in households

4.3.8 These commissioned tables contain information on households for the household activities used within TELMoS14.

4.3.9 The standard table from 2011 Scotland's Census are:

- QS118SC : All families in households, all dependent children in households
- KS601SC : Economic activity, all people aged 16 to 74 Economic activity
- LC6201SC: Economic activity by ethnic group
- QS420SC-Communal establishment management and type - Communal establishments
- DC4414SCca - Communal establishment type by type of resident by sex by age

4.3.10 The processes in the database creation involved:

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

4.3.11 We made adjustments to ensure that all single person households had only one person within them. We then made a correction to the multi-person households to ensure that the total persons and total households were consistent with the Census-based target figure for population and households.

4.3.12 In order to project households and population database from 2011 to 2014, we used the 2014 mid-year population and households estimates[9], published by NRS, to adjust the numbers of population and households in each local authority area.

[8] scotlandscensus.gov.uk

[9] Mid-year population estimates published 30 June 2014

4.4 The Car Ownership database

4.4.1 The DELTA car ownership database contains, for every zone and activity pair, the proportion of households within each of the car ownership levels.

4.4.2 For each household activity and zone within TELMoS14, the database records the proportions in each of three car ownership levels, namely:

- no car
- one car
- two cars or more.

4.4.3 Information on car ownership by household type was taken from customised Census tables commissioned by DSC[10]. This data was converted from 2011 datazone to TELMoS14 zones using a lookup table created by DSC. Car ownership proportions for 2011 were then calculated by household type and zone and the same proportions were applied to the 2014 household database.

4.4.4 The output of this process was a base year file of car ownership proportions by household type and zone.

4.5 Property market data

4.5.1 Floorspace is a fundamental component in the TELMoS14 model as it provides an indication of the capacity of zones in terms of their ability to accommodate households and employment.

4.5.2 TELMoS14 uses rents as the mechanism by which activities (households or employment) compete for and allocate floorspace. The interaction between supply and demand within a TELMoS14 run will determine future rents.

4.5.3 The model represents eight different floorspace types. These are shown in Table 4-4.

Table 4-4 Land Use Categories modelled in TELMoS14

Floorspace Type	Description
1	Residential
2	Retail
3	Office
4	Industrial
5	Warehouse
6	Leisure / Hotel
7	Education
8	Health

4.5.4 Base year estimates of floorspace stocks have been calculated. The methods that have been used are detailed below.

4.5.5 For residential floorspace, we derived information on the dwelling stock from the published Council Tax database and 2011 Census data. The mix of dwellings within

[10] CT_0039b_2011 households type by car ownership level by 2011 datazone

each zone was based upon 2011 Scottish Census[11] data. This showed the proportion of the dwelling stock that were detached, semi-detached, terraced, or flats. The floorspace was then calculated by applying average floorspace per dwelling type, taken from Nationwide Building Society figures, to each zone's mix of dwellings (see Table 4-5).

Table 4-5 Average floorspace per dwelling by dwelling type

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

4.5.6 Information on vacant residential stock was based upon the 2011 Census output and the proportion of vacant dwellings within each zone.

4.5.7 The modelled residential rents were derived from the Registers of Scotland's published house price statistics[12], assuming that rent is 3.5% of selling price, using the average floorspace per dwelling above to convert to rent per m^2, and dividing by 52 to get a weekly rather than annual rent.

4.5.8 There is no publically available data for site level commercial floorspace in Scotland. We therefore calculated the base-year commercial floorspace by applying average floorspace per worker densities to the estimate of employment by land use type for each commercial floorspace type modelled. Average densities were calculated using data from the UK Government's Employment Densities Guide[13].

4.5.9 No commercial floorspace has been included for those workers who work from home.

4.5.10 Vacancy rates for commercial floorspace were based upon various published sources. In particular the "Strategic Review of Town Centres and Retailing in ... – Tayplan macrozone[14]" and "UK Office Market Outlook – H2 2014 – JLL[15]".

4.5.11 Information on commercial rents was drawn from several sources including the Rydens 76th Scottish Property Review and the GVA James Barr report "Scottish town centres April 2014".

[11] Table KS401SC – Dwellings, households spaces and accommodation type at Datazone level, Table 2: Number of dwellings in Scotland by Council macrozone, September 2001-2014, Table 4: Characteristics of dwellings by Council macrozone, 2014

[12] https://www.ros.gov.uk/property-data/property-statistics/quarterly-house-price-statistics.

[13] https://www.gov.uk/government/publications/employment-densities-guide

[14] https://www.google.co.uk/search?q=Strategic+Review+of+Town+Centres+and+Retailing+in+...+%E2%80%93+Tayplan+macrozone&ie=utf-8&oe=utf-8&client=firefox-b-ab&gfe_rd=cr&ei=p9Z0V5ipFunR8gfIrJiIDA

[15] http://www.jll.co.uk/united-kingdom/en-gb/research/242/uk-office-market-outlook-h2-2014

5 TRANSPORT AND LAND USE INTERFACE

5.1 Overview

5.1.1 There is an interface between the Land use (TELMoS14) and Transport (TfMS14) Models that passes data between the two models.

5.1.2 The transport model requires employment and demographic data as a basis for travel demand. These data, in the form of population and household data by type and socio-economic status, are output into formatted files by zones and transferred to the transport model. The output data also includes specific types of employment sectors. An enhancement to output data by income segment was developed during the TELMoS14 project but is not currently required by TMfS14 and is therefore not in use.

5.1.3 The land-use/economic model requires data describing how easy or difficult it is to travel or to move goods between any two zones, or within any zone ("intrazonals" movements). Ease or difficulty of movement is usually measured in terms of generalised costs, which in general reflect the time taken for the journey (including, for public transport journeys, access to/from stations, waiting time, etc.), its money cost and key elements of "inconvenience" such as congestion on roads or the number of changes between trains.

5.2 Generalised cost data from Transport Model

5.2.1 Generalised costs data is generated as an output from the Transport Model and supplied as inputs to the Land Use Model. The costs files are matrices showing costs between zone pairs, including intrazonals, for all the relevant transport travel purposes and the modes (see Table 5-1).

Table 5-1 Purpose and mode combinations for which TMfS14 provides generalized cost matrices to TELMoS14

Purpose Code	Mode Code	Purpose Description	Mode Description
1	1	AM peak in Work	Car
1	2	AM peak in Work	Public Transport
2	1	AM peak non Work	Car
2	2	AM peak non Work	Public Transport
3	1	AM peak LGV	Car
4	1	AM peak HGV	Car
5	1	Inter Peak in Work	Car
5	2	Inter Peak in Work	Public Transport
6	1	Inter Peak non Work	Car

Purpose Code	Mode Code	Purpose Description	Mode Description
6	2	Inter Peak non Work	Public Transport
7	1	Inter Peak LGV	Car
8	1	Inter Peak HGV	Highway
9	1	PM peak in Work	Highway
9	2	PM peak in Work	Public Transport
10	1	PM peak non work	Highway
10	2	PM peak non work	Public Transport
11	1	PM peak LGV	Highway
12	1	PM peak HGV	Highway

5.3 Planning data from Land use Model

5.3.1 There is an interface definition file which is used to specify a miscellany of information used in the TELMoS14/ TMfS14 interface programs, including:

- information regarding the aggregation of the TELMoS14 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.

5.3.2 The specific details in the interface definition file are:

- ratios used in splitting workers into full and part time working and all adults into male and female. These proportions have been worked out from the 2011 Census data.
- definitions to output households by car ownership level into three household types by adult size namely one adult, two adult, and three plus adults[16].
- total employment and specific employment sectors namely agriculture, fishing, retail, hospitality, local financial, education, health and social services are defined. The total employment includes all jobs (quasi and non-quasi[17]); the specific sectors exclude the quasi jobs.

5.3.3 Program, ITMFS tabulates TELMoS14 outputs in the formats required by TMfS. This outputs two files

- TMfS<><>.CSV, containing zonal information on persons by person and household type; and

[16] the two plus adult households data is disaggregated into two adult and three plus adult households using a probability function that has been calibrated to match the distribution of these household types in the 2011 Census

[17] see 4.2.5.

- TAV_<><>.CSV, containing zonal information on households and on employment in selected aggregations of sectors.

5.3.4 An additional synthesized matrix of freight vehicle movements, produced by program MF12, is passed from TELMoS14 to TMfS14.

6 SCENARIO IMPLEMENTATION

6.1 Overview

6.1.1 TELMoS' scenario describes the overall level of economic and demographic growth for Scotland over the forecast period. These have been based upon independently derived forecasts.

6.1.2 In the fixed scenario version of TELMoS14 (which is described in this Report) the changes in the number of households, population and employment at the national level are fixed. They do not vary in response to different land use and transport policies.

6.1.3 The model has:

- a scenario matching test; and
- a reference case.

6.1.4 The scenario matching test is constrained to be consistent at both national and regional levels with the independent forecasts. There is an assumption that those forecasts assume that growth in households and employment is not constrained by the supply of dwellings or commercial property. The scenario matching test has synthesised inputs for future land use reflecting this assumption.

6.1.5 The reference case differs from the scenario matching test in that its inputs on the scale and location of future planned development are based upon information provided by the local planning authorities. This supply may be greater (or less) than the synthesised inputs to the scenario matching test. Similarly, its distribution across zones may differ from the synthesised data. These differences may influence the calculations of accessibility to employment opportunities. This in turn may dampen (or improve) the economic prospects across Scotland. The levels of growth in different regions may 'pivot' around the scenario matching test's forecasts accordingly.

6.2 Employment/economic scenario

6.2.1 The economic scenario has been implemented at two geographic levels. Firstly at the national level where the model has been calibrated to be consistent with independent forecasts, provided to Transport Scotland, by Experian. Secondly at a regional level where the scenario matching test's forecast has been controlled to be consistent with Experian's regional level forecasts. The reference case pivots around these forecasts at the regional level. The construction of the national and regional level scenarios is described below.

6.2.2 Using National Input-Output tables for Scotland[18] (2011) and Experian forecasts for sectorial growth we matched both of the independent sources' sector classifications to TELMoS14 employment activities and reproduced a national input-output table for Scotland by TELMoS14 activity. This was then forecast forward to a 2014 base year using sectorial growth rates calculated from the Experian data and 2014 prices using the deflator provided by WEBTAG[19].

6.2.3 All components of final demand (including household consumption expenditure, government expenditure, investment, and exports) and total output (including imports, total domestic consumption and GVA) were assumed to grow at the same rate as intermediate demand and consumption for all sectors. Minimal scaling was applied to the separate components of Final Demand to ensure Intermediate Demand and Total Demand by sector grew at the same rate (where Total Demand is the sum of Intermediate Demand and Final Demand). Growth rates by sector have been derived from the independent Experian forecasts.

6.2.4 The base year 2014 Regional Economic Model was calibrated to reproduce the Scottish economy's sectorial mix as described by a combination of using National input-output data from the National Accounts and independent sectorial forecasts provided by Experian. The Regional Economic Model works with economic sectors rather than activities and at the macrozone rather than zone level within TELMoS14. The correspondence between TELMoS14 employment activities and sectors is described in Table 6-2.

6.2.5 Employment at both the zone and macrozone level are consistent within TELMoS14. In the base year, data from the employment database (described in Section 4) forms the basis for the regional economic database. In future years the REM drives growth in employment by sector.

6.2.6 A spreadsheet version of the Regional Economic Model was set up to reproduce an input-output table of the whole Scottish economy for the forecast period for which Experian forecasts of Employment and GVA were supplied (2014-2037).

6.2.7 This was implemented by calculating growth in GVA by sector for each of the TELMoS14 Regional Economic Model sectors from the Experian forecasts and applying this growth to each component of Total Demand, Total Output and Final Demand. Intermediate Demand and Intermediate Consumption, as well as the input output coefficients input to the TELMoS14 package, were then derived through implementing a process of iterative proportional fitting within the spreadsheet version of the model so that the National economy grows in line with the Experian independent forecasts as well as maintaining the overall sectorial structure of the economy as identified by the National Accounts.

6.2.8 For the period 2037-2042 the same process as described above was implemented however GVA growth rates by sector for those years were extrapolated from Experian forecasts (ending in 2037).

6.2.9 Future year employment by TELMoS14 activity and sector was forecast, by applying Experian employment forecast growth rates to base year database employment. For

[18] http://www.gov.scot/Topics/Statistics/Browse/Economy/Input-Output/Downloads

[19] https://www.gov.uk/government/publications/webtag-tag-data-book-november-2014

the years 2037-2042 employment growth was, again, extrapolated using data provided by Experian.

6.2.10 As mentioned above, employment growth by sector is driven by the Regional Economic Model. Having derived an economic and employment scenario by TELMoS14 Regional Economic Model sector from the Experian data we calculated coefficients for productivity per worker by sector for the whole of the forecast period. These were then implemented in the model so as to reproduce the independent employment growth forecasts at the National level.

6.2.11 Further matching of TELMoS forecasts to independent forecasts at a sub-national level has been applied. This is an approach that was first applied in TELMoS07. To do this, targets are set for the level of employment growth in each region. Adjustments are then made to the representation of economic capacity, at regional level. These affect the demand for labour and hence the level of employment. In TELMoS07 the calculation of the 'correct' levels of capacity were made by "manual" adjustment via spreadsheet calculations; in TELMoS14 the calculations are part of the modelling process.

6.2.12 Economic Capacity is modelled within the Regional Economic Model. This is a part of the TELMoS14 package that operates at the macrozone level rather than the finer zone level. The regions used were defined in terms of aggregations of the macrozones. They approximate to the Strategic Development Plan Areas where appropriate. A full list of the Regions is provided in Table 6-1 and mapped in Figure F-3 in Appendix F.

Table 6-1 Definition of Regions used within the Economic Scenario

Region	Macrozones
SESplan	1, 2, 3, 4, 9 and 13
Glasgow and Clyde Valley	10, 11, 12 and 44
Nestran	19, 20, 21 and 39
TAYplan	14, 15, 17, 18 and 42
Ayrshire Authorities	7,8, and 34
Dumfries and Galloway	5, 6, 37 and 38
Falkirk, Clackmannanshire and Stirling	16
Highland, Argyll and Moray	22, 23, 24, 25, 26, 27, 28, 29, 30,31, 32, 33, 36, 43,
Eilean Siar	35
Orkney	40
Shetland	41

Table 6-2 TELMoS14 Employment activities and corresponding Regional Economic Model Sectors

Av	Employment activities[20]		REM sector	REM Sect
41	Agriculture, forestry and fishing (non_manual)	101	Agriculture, Forestry & Fishing	101
42	Agriculture, forestry and fishing (manual)			
77	*Agriculture, forestry and fishing QW*			

Av	Employment activities[20]		REM sector	REM Sect
43	Coal and lignite non manual	102	Coal and lignite	102
44	Coal and lignite manual			
78	*Coal and lignite QW*			
45	oil and gas non manual	103	Oil and gas	103
46	oil and gas manual			
79	*Oil and gas QW*			
47	Other Extraction & Mining (non-manual)	104	Other Extraction & Mining	104
48	Other Extraction & Mining (manual)			
80	*Other extraction QW*			
49	Manufacturing (non-manual)	105-116	Food, Drink & Tobacco	105
			Textiles & Clothing	106
			Wood & Paper	107
			Printing and Reproduction of Recorded Media	108
			Fuel Refining	109
			Chemicals	110
50	Manufacturing (manual)		Pharmaceuticals	111
			Rubber, Plastic and Other Non-Metallic Mineral Products	112
			Metal Products	113
81	*Manufacturing QW*		Computer & Electronic Products	114
			Machinery & Equipment	115
			Other Manufacturing Transport Equipment	116
51	Electricity,gas, steam and air conditioning supply	117	Utilities	117
52	Water supply; sewerage,waste management and remediation activities			
82	*Energy and water QW*			
53	Construction	118-120	Construction of Buildings	118
			Civil Engineering	119
			Specialised Construction Activities	120
83	*Construction QW*			
54	Wholesale and repair of motor vehicles and motorcycles	121	Wholesale	121
55	Retail non Local	122	Retail	122
56	Retail Local			
84	*Retail QW*			
57	Transport	123-124	Land Transport, Storage & Post	123
58	Storage		Air & Water Transport	124
85	Transport QW			
59	*Accommodation, food service activities and*	125-126	Accommodation & Food Services	125

Av	Employment activities[20]		REM sector	REM Sect
	recreation		Recreation	126
86	*Accommodation, food service activities and recreation QW*			
60	Information and communication	127-129	Media Activities	127
			Telecoms	128
			Computing & Information Services	129
87	Information and communication *QW*			
61	Very specialized services	130	Very specialized services	130
62	Highly concentrated Business Services	131	Highly concentrated Business Services	131
63	Moderately concentrated Business Services	132	Moderately concentrated Business Services	132
64	Moderately dispersed Business Services	139	Moderately dispersed Business Services	139
65	Highly dispersed Business Services	140	Highly dispersed Business Services	140
88	*Business services QW*			
66	Monetary intermediation Non local	133	Monetary intermediation Non local	133
67	Monetary intermediation local	141	Monetary intermediation local	141
68	Insurance Non Local	134	Insurance Non Local	134
69	Insurance Local	142	Insurance Local	142
70	Public administration and defence; compulsory social security Local	135	Public Administration & Defence	135
71	Public administration and defence; compulsory social security Non-Local			
89	*Public admin QW*			
72	Higher Education	136	Education	136
73	other Education			
90	Education QW			
74	Human health and social work activities	137	Health Residential Care & Social Work	137
91	Health etc QW			
75	Other service activities (22, 23, 24) non manual	138	Other Private Services	138
76	Other service activities (22, 23, 24) manual			
92	*Other services QW*			

Note: Activities 55-56 make up "Retail", activities 61 to 69 inclusive make up "business services", activities 70-71 inclusive make up "Public administration".

6.3 Airport Scenarios

6.3.1 In TELMoS14 there are four airport zones. These represent Edinburgh, Glasgow, Prestwick and Aberdeen airport.

6.3.2 Assumptions were made on the level of growth within the airport zones. These were based upon the Department for Transport's UK aviation forecasts, published in

2013[21]. These contain passenger forecasts for the major UK airports including those described above.

6.3.3 Airport related employment at Edinburgh, Aberdeen and Prestwick Airports is assumed to grow in line with the DfT Forecasts. Transport Scotland advised that for Glasgow Airport TELMoS14 should use the same growth scenario that had been applied for recent transport appraisal work. This was based upon the 2011 Glasgow Airport Master Plan[22].

6.4 NRS based demographic scenario

6.4.1 The demographic scenario for TELMoS14 is based on the National Records of Scotland's (NRS) Household Projections for Scotland (2012 based) and the NRS Projected Population of Scotland (2012 based). The projections are published in 5 year increments from 2012 to 2037.

6.4.2 Again, TELMoS14 was calibrated so that its national level demographic growth is consistent with these independent forecasts. This involved the following steps:

- The creation of a set of targets for the number of households by household type for the period to 2037 that are consistent with the 2012 based NRS forecasts. The NRS Household projections have fewer household categories than TELMoS14. Some NRS household categories were disaggregated based upon Census data (and the TELMoS base year household numbers described in Section 4).
- Where an NRS category, such as single person households, is sub-divided into TELMoS14's young single, older single and retired single categories, then a calculation was made of how the proportion of young, older and retired change over time, based upon the NRS population projections.
- The creation of a set of population targets by TELMoS14's three person types (children, retired and working age adult) based on the household targets that are consistent with the 2012 based NRS population forecasts.
- For the period from 2037 to 2042 (i.e. beyond the NRS forecast period) the targets were extrapolated.
- The NRS population projections provide forecasts of net-migration (of people). For TELMoS we model migration in terms of the in-flow and out-flow of households to/from Scotland. The conversion of net-migration flows of people to flows of households involved the following steps. Firstly, to use historic migration data[23] to create an age profile of in- and out- migrants. Secondly, to create a forecast of future migration based upon this age profile and the NRS 2012 based population projections of net migration. Finally, to create a household profile for inward and outward migration that was consistent with the population forecast of migration described above.

[21] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223839/aviation-forecasts.pdf

[22] http://www.glasgowairport.com/media/37875/draft-master-plan-web-small-4.pdf

[23] NRS Website file D1-overseas-mig-flows-by-age-scotland-2001-02-latest-jul15.xlsx

- The generation of a set of coefficients for input into TELMoS14's household formation, transition and distribution model that generated, at national level a forecast of households consistent with the household targets described above.

6.5 Match to targets

6.5.1 In this section we demonstrate the consistency of the TELMoS14 model forecasts with the independent forecasts. The following compare:

- TELMoS14's national employment forecasts with the Experian economic forecasts;
- TELMoS14's regional economic forecasts with the Experian economic forecasts (for Tables see Appendix B); and
- TELMoS14's national population and household forecasts with NRS 2012 based population and household projections.

6.5.2 Figure 6-1 compares the TELMoS14 forecasts of national employment with the independent forecast, commissioned from Experian. The two forecasts match closely throughout the forecasts period. The difference between the forecast values in any one forecast year is always less than 0.16%.

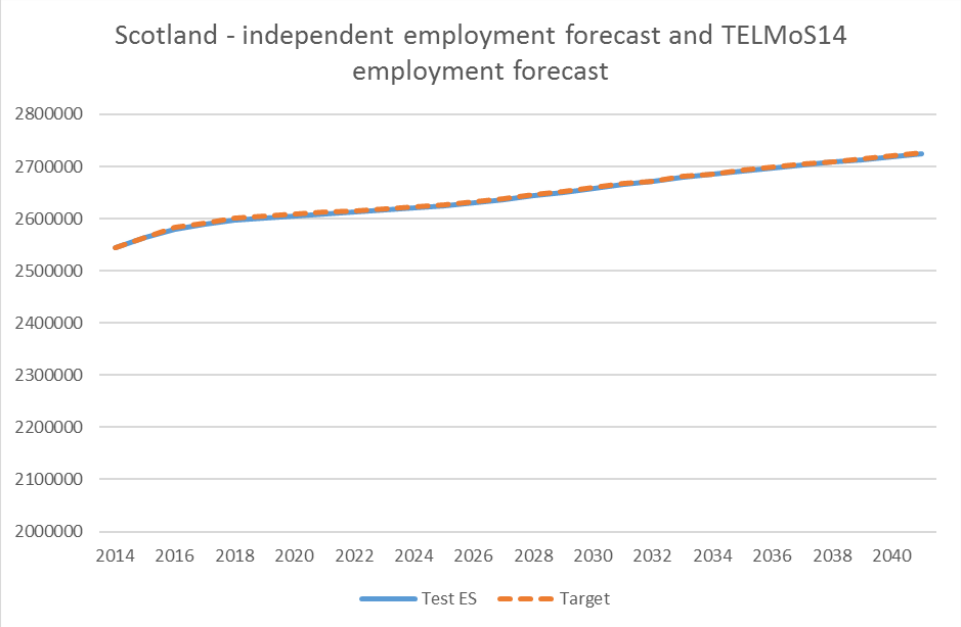


Figure 6-1 Comparison of total employment growth and the 'target' forecast

6.5.3 Appendix B contains a comparison of the TELMoS14 scenario base forecasts of regional employment with the independent forecasts. This comparison is made for all 11 regions. Again there is a good fit between the forecasts of future employment made by TELMoS and those of the independent forecasts.

6.5.4 The target population figures are based upon the NRS 2012 based population projections. Figure 6-2 shows a comparison, at national level, of the target and the TELMoS14 forecast. The TELMoS forecast of population growth is consistent with the independent forecast.

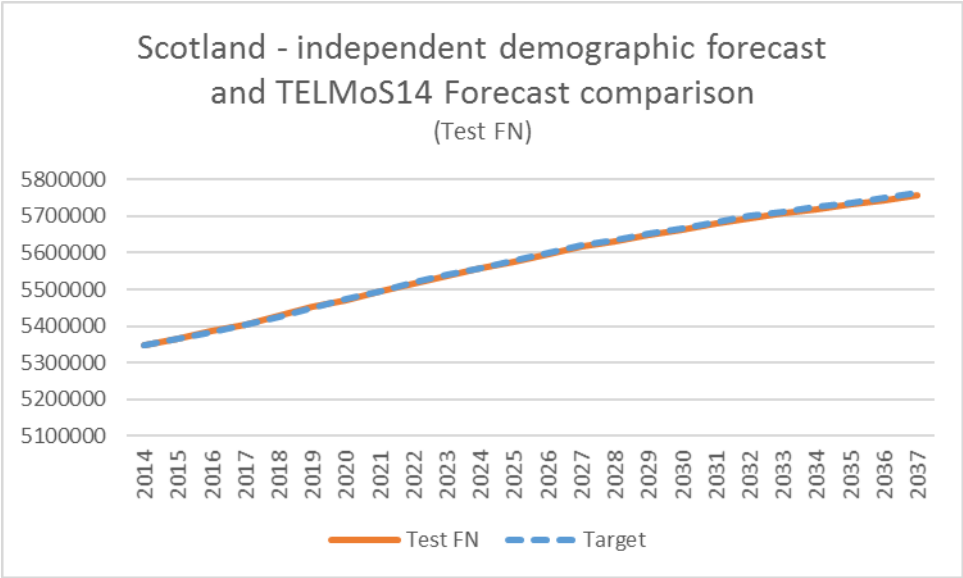


Figure 6-2 Comparison of total population growth and the 'target' forecast

6.5.5 Appendix B makes a comparison between the target forecasts and the TELMoS14 forecast for the following three population groups: Children, Working Age Adults and Retired Persons. These are the three population age groups modelled within TELMoS. The comparison shows that the two forecasts are virtually identical at national level.

6.5.6 Figure 6-3 compares the forecast of number of households against the independent forecasts. A comparison by the eight broad categories modelled in TELMoS14 is described in Appendix B.

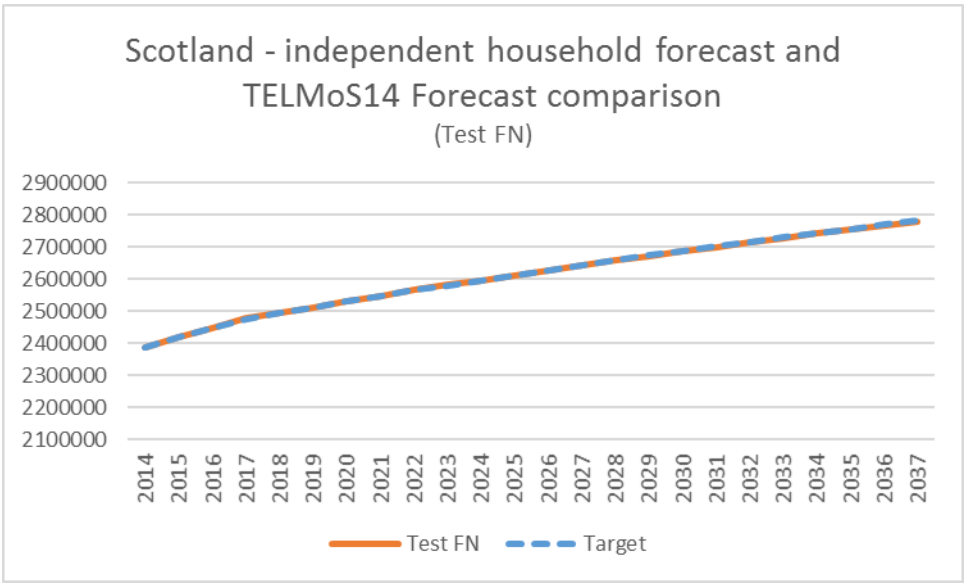


Figure 6-3 Comparison of total household growth and the 'target' forecast

7 LAND-USE POLICY INPUTS

7.1 Overview

7.1.1 The land-use policy inputs are one of the key inputs to the TELMoS model. They inform the modelling of development. They are based upon information provided by the 32 local planning authorities and 2 national park authorities and describe the scale and location of planned development.

7.1.2 Information is included for all eight of the land uses modelled within TELMoS (see Table 4-4 for definitions). Planning policy information was collected in 2014 as part of a joint exercise involving Transport Scotland and Scottish Water. A description of the data gathering and processing of the data for input into TELMoS was included in the (separate) APPI2014 Report[24].

7.1.3 In this section we summarise the inputs at national level. Tabulation of planning policy inputs, at Local Authority level are detailed in Appendix C.

7.2 Information provided by the local planning authorities

7.2.1 Local authorities were asked for detail of the scale and phasing of:

- Sites with planning permission for development;
- Allocations in local plan documents;
- Other sites that were likely to come forward and be made available for development during the period to 2037; and
- Sites where demolition of existing land use was expected

7.2.2 Site level data was aggregated to TELMoS zone level. Further processing was undertaken to convert information on the size of planned development to floorspace. This was necessary as TELMoS' development model calculates changes in floorspace (for each land use) rather than changes in hectarage of land.

7.3 Planned Development

7.3.1 Table C-1 in Appendix C shows the number of dwellings (and equivalent residential floorspace) that are expected to come forward for development over the forecast period within each Local Authority area. There is provision for over 400,000 dwellings to be built in the period to 2037. The information is shown as both dwellings and residential floorspace.

[24] "Assembly of Planning Policy Inputs 2014 – Final Report'. Report prepared by DSC for Transport Scotland under the LATIS Lot 3 Framework.

7.3.2 Table 7-1 shows the amount of commercial and other non-residential floorspace, by land use type, that is expected to come forward and be available for development in the period to 2037.

Table 7-1 Summary Commercial and Non-Residential Planning Inputs

Land Use	2015-2017	2018-2022	2023-2027	2028-2032	2033-2037
Retail	669600	810400	505200	146700	4200
Office	1764900	6185100	3364000	586700	158400
Industry	1155100	4470000	2952800	1128400	367100
Warehouse	932600	2924600	2022800	679000	220200
Leisure	306400	406100	149200	35500	2300
Education	54300	69200	36200	6400	0
Health	72300	75300	27900	13500	11300

7.3.3 Appendix C shows more detailed inputs of each commercial floorspace type that are expected to come forward for development over the forecast period within each Local Authority.

7.3.4 Table C-2 shows the retail planning inputs for each Local Authority. Provision for over 2.1million square metres of floorspace have been identified. Half of this is within Aberdeen and Falkirk authorities.

7.3.5 Table C-3 shows the office planning inputs for each Local Authority. Provision for over 12million square metres of floorspace have been identified. Over 40% of this is within Edinburgh and West Lothian.

7.3.6 Table C-4 shows the industrial planning inputs for each Local Authority. Provision for over 10million square metres of floorspace have been identified. Around 18% of this is within North Lanarkshire.

7.3.7 Table C-5 shows the warehouse planning inputs for each Local Authority. Provision for over 6.7million square metres of floorspace have been identified. The two main concentrations are in Aberdeenshire and North Lanarkshire.

7.3.8 Tables C6-8 show the planning inputs for Leisure and Hotel, Education and Health. Around 900,000 m^2 of leisure and hotel-related development and under 250,000 m^2 of both education and health related development are expected to come forward and be made available in the period to 2037.

8 ACCESSIBILITY CALCULATIONS

8.1 Overview

8.1.1 This Chapter documents the accessibility calculations in the TELMoS14 model.

8.1.2 Program AC14 calculates accessibility within the TELMoS14. This takes the generalised costs that are generated by the transport model and calculates:

- accessibility for each measure (see Table 5-1); and
- accessibility for each household and employment type (see Table 4-2 and Table 4-3)

8.1.3 The outputs from the model are a set of origin and destination accessibilities for household and employment activities.

8.1.4 The running of the Accessibility model involves:

- averaging generalised costs across modes (for passenger travel only);
- calculating a range of accessibility measures at zonal level, first by purpose and then by activity; plus
- converting the zonal matrices of generalised costs per trip into macrozone matrices,
- calculating generalised costs per unit of trade at macrozone level, and finally
- calculating measures of market accessibility for each sector, again by macrozone.

8.1.5 The following sections describe these in turn.

8.2 Averaging generalised costs across modes

8.2.1 For passenger travel, the model works on the hypothesis that the different modes of passenger transport are alternative means of getting from origin to destination. It therefore calculates an average generalised cost of travelling between any pair of zones before using those averages to calculate the accessibility measures for each zone.

8.2.2 The sensitivity to differences in generalised costs around varies with the length of the journey. This means that a ten minute difference between two modes will have a major impact on the probability of choosing one rather than the other for a 500 metre journey, but little impact on the probabilities for a 500Km journey.

8.2.3 Average generalised costs are calculated using a logsum formula. This is a standard method in transport analysis, based on random utility theory. It assumes that:

- each person choosing between alternative modes of transport for a given journey will choose the alternative which appears to them to involve the least generalised cost;
- each person perceives a generalised cost for each alternative which is drawn from a distribution around the modelled generalised cost;
- in modelling, we cannot know what generalised cost each individual perceives, but we can describe the distribution of perceived values around the modelled values which the transport model has built up from travel times, costs, waiting penalties and other relevant variables.

8.3 Zonal accessibility measures by purpose

8.3.1 The zonal accessibility measures quantify how easy it is to get from each origin to a range of zones for different types of destinations, and conversely how easy it is for each destination zone to be reached from different types of origins. The measures calculated are listed in Table 8-1.

Table 8-1 Zonal accessibility measures

Measure	Origin (or active) accessibility measures the ease of getting to:	Destination (or passive) accessibility measures the ease of being reached by:	...by purpose of travel:	Purpose
1	jobs SEL1	labour SEL1, AM	Commute	2
2	jobs SEL2	labour SEL2, AM		2
3	jobs SEL3	labour SEL3, AM		2
4	jobs SEL4	labour SEL4, AM		2
5	consumer services	Consumers, IP	Other	6
6	other businesses	other businesses , AM	Business	1
7	jobs (for sending LGV deliveries/services)	jobs (for receiving LGV deliveries/services), AM	LGV	3
8	jobs (for sending HGV deliveries)	jobs (for receiving HGV deliveries), AM	HGV	4
9	jobs (for sending LGV deliveries/services)	jobs (for receiving LGV deliveries/services), IP	LGV	7
10	jobs (for sending HGV deliveries)	jobs (for receiving HGV deliveries), IP	HGV	8

8.3.2 The origin accessibility is a measure of how easily travellers (or goods) can get from each origin zone to the set of opportunities in the destinations in the Modelled Area, for each purpose in the transport model. The calculation is a logsum average, averaging over destinations.

8.3.3 The destination accessibility is a measure of how easily travellers (or goods) can reach each destination in the Modelled Area from all the relevant origins, for each

purpose in the transport model. The calculation is a logsum average, in this case averaging over origins.

8.3.4 The key difference from the averaging over modes is that it takes into account the relative importance of each destination. The logsum average has advantages over a conventional weighted average. The result of calculating the logsum average for each measure and each origin is the "expected average generalised cost" of reaching the relevant type of destination, e.g. of reaching a job of socio-economic level 1, or another business.

8.4 Zonal accessibility measures by activity

8.4.1 The zonal accessibilities by purposes are converted into zonal accessibilities for each activity (for each household or employment type) by a simple weighting.

8.4.2 For households this is a weighting based on trip frequencies. The accessibility is calculated by multiplying the different accessibility measures by the expected frequency (trips per household per week) for each individual household activity.

8.4.3 For employment it is based on varying combinations of:

- 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 HGV movement.

8.4.4 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.

8.5 Generalised costs per unit of trade

8.5.1 For the macrozone level economic modelling, a different approach is taken. The generalised costs by purpose, after the averaging over modes described above, are aggregated into macrozone by macrozone matrices and then converted into costs per unit of trade (that is per £million of goods or services delivered)[25]. For sectors delivering goods, this step combines passenger and freight costs; for services, it is based purely on passenger travel.

8.5.2 The weighting for each mode of travel, where more than one is involved, is based on getting appropriate average costs of travel as a proportion of total production costs, whilst also obtaining appropriate average distances for trade in each sector.

8.5.3 The output from this step is a set of matrices (one set for each transport model run used) measuring the cost of delivering one unit of output from each sector to its consumers.

[25] IT12 convert area matrices of generalised costs by purpose into area matrices of generalised cost per unit trade.

8.5.4 These costs are used directly in the spatial input-output model, and indirectly in the investment distribution model through the macrozone accessibility calculations described below.

8.6 Measures of market accessibility by sector

8.6.1 The macrozone accessibility measures for each sector and macrozone are measures of "effective market size". They are an indication of how well the market for each sector can be served from each macrozone. The "effective market size" is found by considering, for each producing macrozone and sector, the demand for the sector's output in every macrozone across the country, multiplied by a function of the cost of delivering to that destination, i.e. a "deterrence effect".

8.6.2 The cost is the output from the calculations described in the previous section. If the cost is very low, then the function is close to 1, i.e. there is very little deterrence. As the cost of delivery increases, the function decreases towards 0, i.e. the deterrence effect increases.

8.6.3 Changes in "effective market size" are used as inputs to the investment location model (see section 9).

9 BUSINESS/EMPLOYER RESPONSES

9.1 Introduction

9.1.1 The modelling of the economy and employment is split between four components of TELMoS14, each representing a different process of change:

- the investment/disinvestment model;
- the trade and production model;
- the employment location model;
- the employment status model.

9.1.2 The basis of these is that the first two models represent choices and effects which determine in which part of the country economic activity will occur, at macrozone level, whilst the last two models look at the consequences in relation to local factors such as availability of space and accessibility to labour, at zone level.

9.2 The investment/disinvestment model

9.2.1 The investment/disinvestment model represents longer-term choices about where the capacity to produce goods or services is located. The variables influencing these choices are

- accessibility to markets; and
- costs of location, including costs of obtaining inputs.

9.2.2 Different measures of accessibility are calculated for each sector, taking account of how goods and services are delivered (i.e. the mix of goods and passenger transport required) and the range over which they operate (some are much more localised than others). A given transport change can therefore have marked effects on some sectors in one macrozone, and no direct effect on others.

9.2.3 Costs of location come partly from the input-output model (for costs of physical inputs), partly from the employment location model (costs of labour and space). These are outlined in the following two sections.

9.2.4 The model is one of gradual change, with a proportion of capacity being renewed (or not) each year, and gradual growth or decline which will be defined as part of the input economic scenario. If there is no change in accessibility or other variables, the distribution of capacity will remain unchanged. If one macrozone experiences an improvement in accessibility, it may attract additional investment over time at the expense of other macrozones.

9.2.5 The output of this model is an updated matrix of capacity by macrozone and sector, measured in terms of expected jobs.

9.3 The trade and production model

9.3.1 The trade and production model is a spatial economic model which forecasts how much (in money terms) each sector will produce in each macrozone, given

- the capacity of each macrozone for each sector (updated by the investment model);
- the costs of delivery relevant to the sector (derived from the transport model);
- final demand for exports, government and fixed investment (input as part of the economic scenario);
- final demand for household consumption (from the household modelling); and
- a set of input-output coefficients (defined in the calibration of the model, from national accounts data – see Chapter 6).

9.3.2 The main outputs of this model are

- matrices of trade by sector from macrozone to macrozone
- production by sector and macrozone (in money terms).

9.4 The employment location model

9.4.1 The (zonal) employment location model takes the results of the macrozone level economic modelling and turns it into employment, locating this to zones. In the case of employment that occupies one of the seven non-residential floorspace types, the location of jobs is influenced by the availability of floorspace; for quasi-workers it is implicity assumed their place of work is their place of residence; and for other types of jobs (that are associated with land uses not modelled in TELMoS14), it is implicitly assumed that the supply of space will respond to demand.

9.4.2 The location of jobs in most sectors is influenced by accessibility at the more local level, particularly accessibility to consumers, to labour force and to other local businesses. As noted earlier, accessibility is defined differently for each sector.

9.4.3 A number of sectors are treated as non-responsive including manual workers in Agriculture, Coal, Oil, Mining, and University employment sectors. Employment within these sectors will simply grow or decline in line with the macrozone total.

9.4.4 The outputs from this submodel are

- the location of jobs by zone
- for employment floorspace types, rent and vacancy rates by zone.

9.5 Calibration of the investment, trade and employment location models

9.5.1 The calibration of the models contributing to the location of employment and economic activity has involved a number of overlapping processes:

(a) adjusting the amounts of travel and transport required to deliver one unit of each sector's output from producer to consumers (see section 8);

(b) adjusting the sensitivity of trade patterns to the resulting costs of delivery (which also affects the accessibility to markets for each macrozone and sector);

(c) adjusting the sensitivities of each employment activity to changes in accessibility, and (for those occupying floorspace) adjusting their sensitivities to changes in the cost of location; this also involves considering how space per worker will be adjusted in response to changing rent per unit floorspace;

(d) adjusting the sensitivities to location costs and to macrozone accessibilities (the "effective market size" measures from section 8) in the investment model – which is generally the most important component in determining responses at macrozone and regional levels.

9.5.2 All of these are inter-related. The main aims in calibration have been to adjust (a) and (b) so as to get both sensible base year values for the costs of transport relative to the value of output and sensible values for the distances over which different sectors trade; and (c) and (d) so as to get appropriate responses to accessibility change in terms of (i) rents and (ii) changes in the location of employment. In judging what is sensible and appropriate we have referred mainly to

- evidence on transport costs as percentages of production costs and volumes of travel per unit value from research at Heriot-Watt University[26,27];
- evidence on trade distances from TSGB and Heriot-Watt University[28,29]; data, taking account of the possibilities of multiple handling;
- evidence from hedonic price studies by Dunse and Jones[30];

9.5.3 The production model outputs notional employment by sector, macrozone and SEL as a simple function of production by sector and macrozone. The number of jobs per unit production is an input defined as part of the economic scenario, decreasing over time as productivity increases. The mixture of jobs by socio-economic level in each sector has been assumed constant over time, but could also be changed as part of the scenario.

9.6 The employment status model

9.6.1 The employment status model scales the outputs from the zonal location model (see section 9.4 above) so that jobs by activity and socioeconomic level in each macrozone grow or decline in line with the employment outputs from the REM (see section 6).

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[26] Campbell, J and A McKinnon (1997): *Trends in UK road freight transport.* Report prepared for EU REDEFINE project, Heriot-Watt University.

[27] A McKinnon (2003): presentation to seminar at Transport Studies Unit, University of Oxford, quoting research by A T Kearney (1999).

[28] Campbell, J and A McKinnon (1997): *Trends in UK road freight transport.* Report prepared for EU REDEFINE project, Heriot-Watt University.

[29] A McKinnon (2003): presentation to seminar at Transport Studies Unit, University of Oxford, quoting research by A T Kearney (1999).

[30] 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.

9.6.2 The output of this calculation is the number of workers by workplace zone and SEL. (The same component also forecasts which residents will fill these jobs and hence the proportion of working age adults in each zone are working – see Section 10.6)

9.6.3 The process assumes that all of the defined jobs are filled.

9.6.4 This process applies to each employment activity the proportions of workers by socio-economic level in that activity. This is taken from the initial data i.e. from the 2014 employment database. These proportions have so far been assumed not to change over time, though different assumptions could be implemented as part of an alternative scenario. Note that this no-change assumption applies to each employment activity: the overall mix of socio-economic levels will change as a result of different activities, employing different mixes of workers, growing or declining at different rates.

10 HOUSEHOLD RESPONSES

10.1 Introduction

10.1.1 The version of DELTA implemented in TELMoS14 represents:

- change in household numbers, and the number of household which are mobile in each year;
- migration over longer distances;
- household incomes;
- household location and relocation over shorter distances; and
- employment status and commuting (by persons rather than households)

10.2 Change in household numbers

10.2.1 The change in household numbers is represented by the household transition model. These changes are made by combinations of:

- households transitioning (transforming) from one type to another (i.e. a single young adult becoming a single older adults);
- the dissolution of households (i.e. when two single households merge together to become one couple household, thus removing one household from the model); and
- household formation (i.e. when a grown up child leaves the family home to form a new household).

10.2.2 The outputs from the model are:

- the numbers of surviving households by type in each zone (i.e. households which have not dissolved or migrated away); and
- the number of pool households by macrozone.

10.2.3 At this point in the process the pool households are just the newly formed households; the incoming migrant households are added later by the migration model.

10.2.4 The three processes (transformations, dissolutions and formations) 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 within one year.

10.2.5 Some of the events modelled are represented by a single rate (e.g. the probability that a household's first child will be born during the year, which gives the

probability of a single transformation); other events require two or more changes (e.g. the co-habitation of two single persons, which is treated as a transformation and a dissolution).

10.2.6 All of 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.

10.2.7 A remaining function of the transition sub-model is to define which households are "mobile" in the location sub-model. All newly formed, newly arrived or newly transitioned households are assumed to be mobile, along with a proportion of wholly unchanged households. These proportions are input into block CTMT07 in MT12 input file.

10.3 Migration

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

- the proportion of adults in work;
- a population density measure, as a proxy for life-style factors; and
- rents.

10.3.2 The outputs of this model – the movement of households from one macrozone to another – are an input into the household location model, where the households are included, along with the mobile and pool households, and assigned to zones.

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

10.3.4 The inputs to the migration model are illustrated in Figure 10-1.

10.3.5 The model works on the number of households (top of Figure 10-1) 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 macrozones (lower left); this is stronger than the other economic effect, which is the effect of housing costs (upper left), which to some extent discourages moves from cheaper to more expensive macrozones.

10.3.6 Other migration effects are essentially 'life-style' effects e.g.:

- Younger persons tending to move towards higher density macrozones
- Older persons tending to move away from higher density macrozones.

10.3.7 The variables driving these effects are input as macrozone constants.

10.3.8 Distance controls in the MM12 input file specify that the minimum distance to model migration is zero (i.e. migration is modelled between all macrozone pairs in the fully modelled area); however, the minimum distance for the full effect of the model migration flow is 40km.

10.3.9 The migration model input ultimately takes the coefficients of the migration effecting variables as 'push' and 'pull' factors, where the 'push' and 'pull' factors

are the same variables but with opposite signs. This is a condition which has been imposed in applying the model.

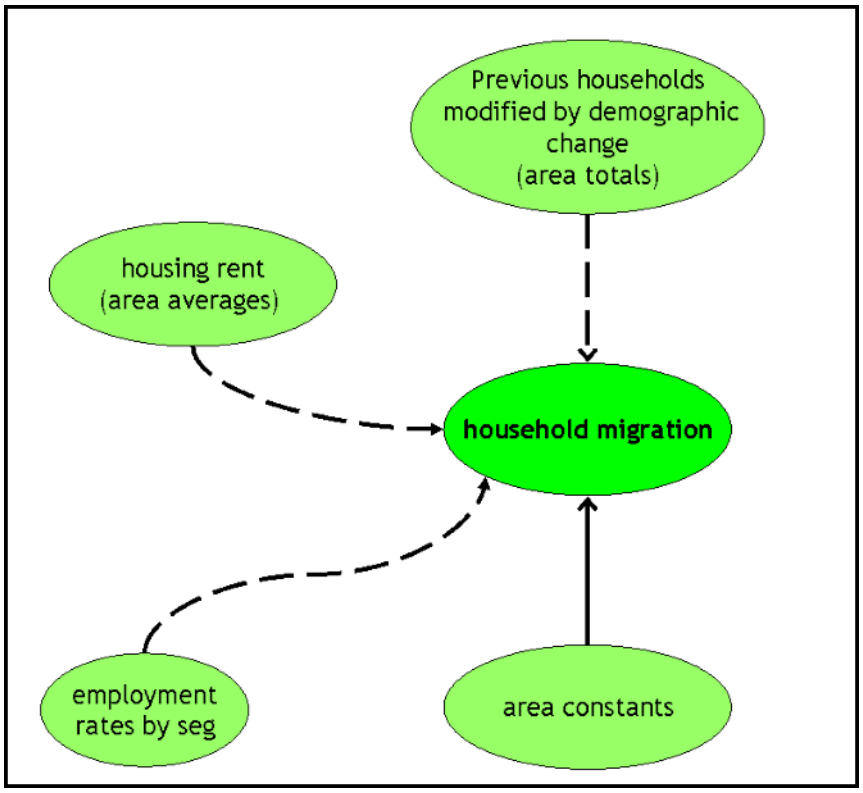

Figure 10-1. Migration model: inputs

10.3.10 Research on migration, based on analysis of the Census and other sources, has found that most household moves are over short distances and below the range of the migration model; nevertheless, the migration model 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 macrozone will change the rates of migration to and from that macrozone.

10.4 Household incomes

10.4.1 Household location is strongly influenced by household incomes which are calculated by the income model based on the household type and the average number of workers per household (if any) in that household type in that zone.

10.4.2 TELMoS14 assumes that the numbers of workers within a household may change. This affects calculations of income. Specifically, 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 this calculated income in the car ownership model (MC12) and the household location model (ML12), where it is used as the "expected income" for household moving to that zone)

10.4.3 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 and marginal) for forecast years. These are input, to the model, in the LCML01 block of the ML12 input files. The rates of income growth are based on National GVA and household growth, which in turn are based on the economic and demographic scenarios.

10.5 Car ownership

10.5.1 Car ownership is forecast using an adaptation of the Department for Transport's NATCOP model. This used in TELMoS14 to forecast conditional car ownership probabilities by household type, zone and year, i.e. what proportions of households of a given type will own 0, 1, 2 or 3+ cars **if** they locate in a particular zone in the current year?

10.5.2 The application of the model in TELMoS14 is incremental, i.e. it starts from the proportions of households by type and car ownership estimated from Census data, and adjusts those proportions each year. The variables affecting the car ownership probabilities are

- average income per household;
- average workers per household;
- licence-holding for adults of this household type;
- proportion of households of this type having one or 2+ company cars;
- an index of car running costs;
- an index of car ownership costs.

10.5.3 The income and workers per household terms are calculated within the model (see sections on incomes and employment status). The other variables are all input to the model. Note that the car running cost index input by the user and is **not** a transport model output (though TMfS14 outputs could undoubtedly be used to revise it if appropriate). In previous TELMoS work, the car ownership cost index has on occasion been adjusted in order to constrain the total numbers of cars in particular groups of zones. A process to automate that kind of adjustment is under development.

10.5.4 We are aware the new research has been carried out to update and refine the NATCOP model in the light of 2011 Census and other more recent data. Work is starting on some minor DELTA enhancements that will allow the (as yet unpublished) results of that research to be used in a future update of TELMoS14.

10.6 Household location/housing market model

10.6.1 The household location model assigns mobile households to zones. The mobile households in any one year consist of:

- newly formed households (transition model);
- long distance migrating households (migration model); and
- the proportion of households already located within an macrozone but looking to move (short distance moves; transition model)

10.6.2 The four key influences on location choice are:

- Accessibility
- Housing quality
- Available floorspace
- Cost of location

10.6.3 The outputs from the location model are:

- The number of households within each zone;
- The amount of occupied floorspace;
- The amount of vacant floorspace; and
- The floorspace rent levels.

10.6.4 The household location model treats floorspace as a continuous variable, with households being able to occupy more of less of it: if rents go up, they will occupy less, and vice versa.

10.6.5 Not all household locate or re-locate in each year; younger households are more mobile, older households less so. As a result, only a minority of households and of the housing supply is considered (by the Location Model) in any one year of the model.

10.6.6 There are inherent tensions in the model: 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.

10.6.7 The inputs and the model process are illustrated in Figure 10-2. 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.

10.6.8 The lower left of the diagram represents the calculations which produce the cost of location and floorspace per household variables. These new values are affected by the rents, which are calculated within the model by finding a short term equilibrium between the supply and demand of housing.

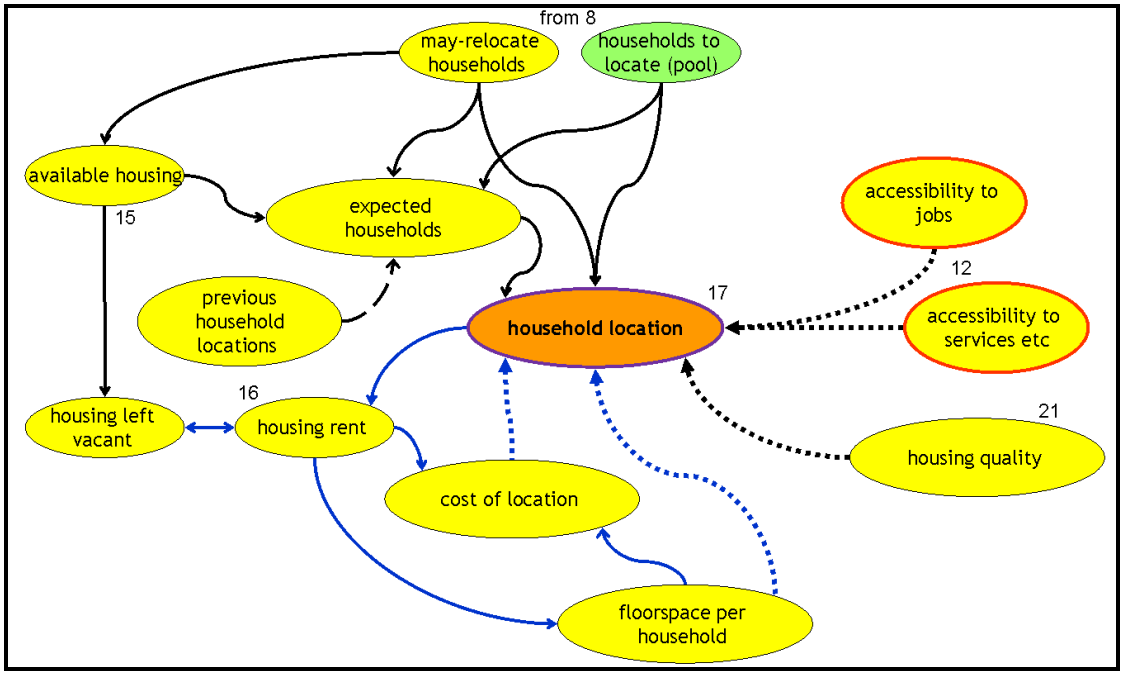

Figure 10-2: Household Location Model: inputs and processes

10.7 Employment status

10.7.1 The employment status model has three main functions:

- to take the jobs by sector and SEL, and to adjust the labour supply (by increasing the numbers of adults of working age in employment) to match these jobs by SEL;
- to calculate the numbers of children and people in retirement within each zone; and
- to create matrices of travel to work.

10.7.2 The outputs from the employment model are:

- the number of persons by the four population groups modelled within TELMoS14;
- the number of jobs by socio-economic level; and
- the travel-to-work matrices.

10.7.3 The number of households by type and zone do not change within a run of the employment status model. Note that this is the one component of the household/population modelling which works in terms of persons rather than households.

10.7.4 Within the TELMoS14 land use model it has been calibrated so that the total population and persons by type matches the NRS 2012 based population projections. The numbers of persons in work are adjusted to match the numbers of jobs; the number of non-workers is the residual of the working age population.

11 DEVELOPER RESPONSES

11.1 Design of the model

11.1.1 The TELMOS14 model considers eight types of floorspaces: housing, retail, office, industry, warehouse, leisure/hotels, education and health.

11.1.2 The development model works separately for each floorspace type. It calculates:

- the amount of development started in each year; and
- allocates this to zones, subject to the amounts of development permitted at the time.

11.1.3 The amount of development started is defined as a fraction of the total stock at the beginning of the year.

11.1.4 The allocation of development is based on

- the amount of development permissible (i.e. the planning policy inputs, including unused permissible development from previous years) and
- the profitability of development, estimated as the most recent rent minus a typical construction cost (converted to rent-equivalent terms): developers will prefer to develop where it is more profitable to do so. The development costs are calculated for different development processes and for the brownfield sites these depend on site preparation and remediation needed in making these sites available for development (see Appendix D).

11.1.5 TELMoS14 models four development processes. These are:

- Greenfield development;
- Low Cost Brownfield development on sites with low site preparation costs;
- Medium Cost Brownfield development on sites with site preparation costs relating to removal of previous infrastructure and pollutants;
- High Cost Brownfield development on sites with significant contamination.

11.1.6 These categories are based upon English Partnership Best Practice Note 27, "Contamination and Dereliction Remediation Costings.[31]

11.1.7 A calibration of the development model by adjusting the fraction of the total stock was carried out so that the total developed floor for the whole of Scotland, subject to viability of development (see Appendix D) and local planning constraints, is consistent with the economic and demographic scenarios.

[31] http://www.regenerate.co.uk/EP_Contamination%20&%20Remediation%20costs.pdf

11.1.8 The Model ensures that the results of the allocation process at the more disaggregate zonal level does not exceed the amount of permissible development.

11.1.9 There is a timelag between the modelled development start and the resulting floorspace becoming available to occupiers: one year for housing and two years for non-residential floorspace.

11.1.10 Figure 11-1 to Figure 11-6 compare, for each modelled land use, the total amount of permissible floorspace, the forecast of developed floorspace and the growth in the activity (i.e. households or employment) that occupy that land use.

11.1.11 Figure 11-1 shows the forecasts for residential floorspace and households. The green line represents the cumulative amount of permissible residential floorspace, the orange line the quantity that is developed. The blue line represents the demand for residential floorspace (in terms of the number of forecast households). The quantity of permissible floorspace 'tails off' towards the end of the forecast period. By 2037 virtually all of the residential floorspace is modelled as developed. The increase in residential floorspace over the period from 2014 to 2037 is broadly consistent with the increase in the number of households.

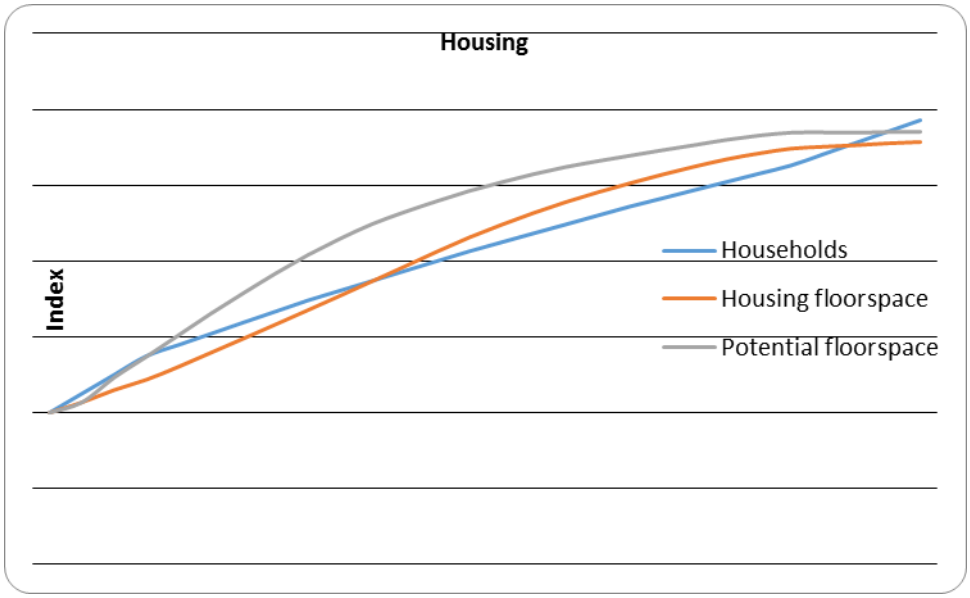

Figure 11-1 Growth in Housing floors and total households (Test FN)

11.1.12 Figure 11-2 shows the forecasts for retail floorspace and retail based employment. The economic scenario suggests little or no change in the number of retail related jobs. In contrast the permissible development implies that there is potential for around a 20% increase in retail floorspace, if all of the permissible development was taken up. The model has been calibrated so that a small proportion of the retail permissible development is forecast to be built. This will permit some movement of retail employment, possibly to new relatively attractive locations, in terms of accessibility and from existing retail locations (with relatively poor accessibility).

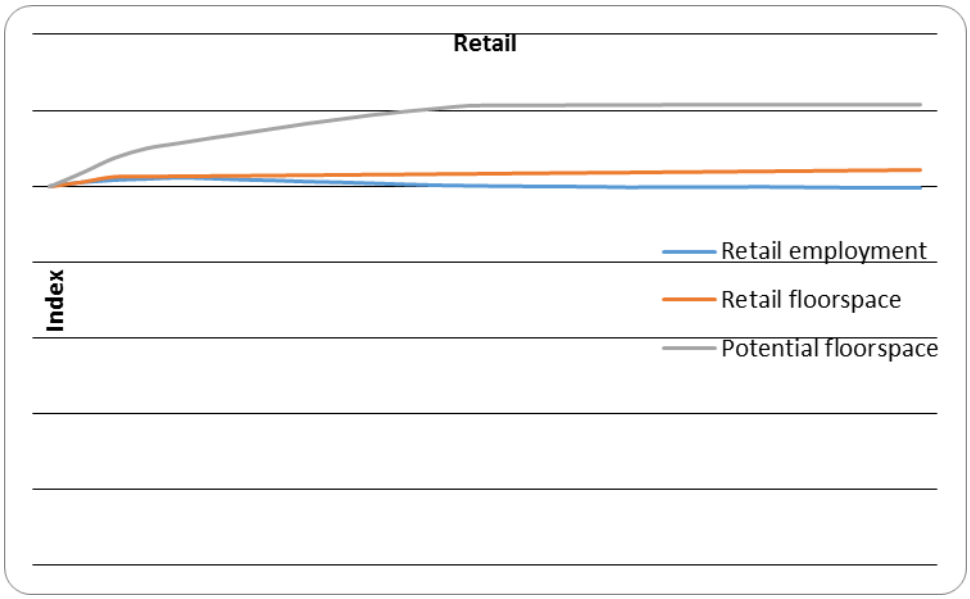

Figure 11-2 Growth in Retail floor and total retail employment (Test FN)

11.1.13 Figure 11-3 shows the forecasts for office floorspace and office based employment. The economic scenario suggests little or no change in the number of office related jobs in total. In contrast the permissible development implies that there is potential for around a 100% increase in office floorspace, if all of the permissible development was taken up. The model has been calibrated so that a small proportion of the office permissible development is forecast to be built. This will permit some movement of office employment and will meet the demand for more office floorspace from those office-sectors that are growing, in the locations that they favour.

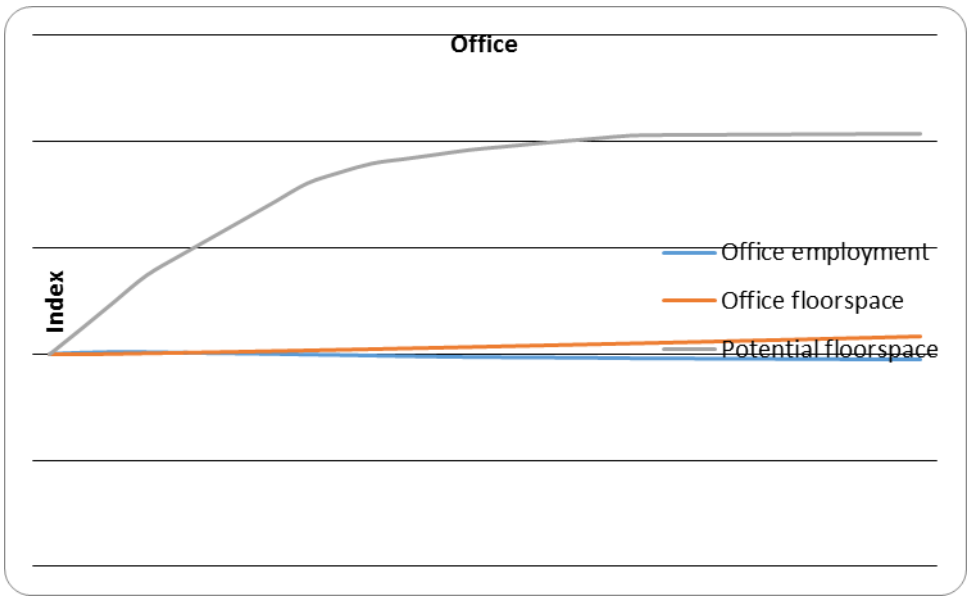

Figure 11-3 Growth in Office floor and total office employment (Test FN)

11.1.14 Figure 11-4 shows the forecasts for industrial floorspace and industrial based employment. The economic scenario suggests a small increase in the number of industrial-related jobs in total. In contrast the permissible development implies that there is potential for around a 60% increase in industrial floorspace, if all of the permissible development was taken up. The model has been calibrated so that a small proportion of the industrial permissible development is forecast to be built. This will permit some movement of employment and will meet the demand for more industrial floorspace from those sectors that are growing, in the locations that they favour.

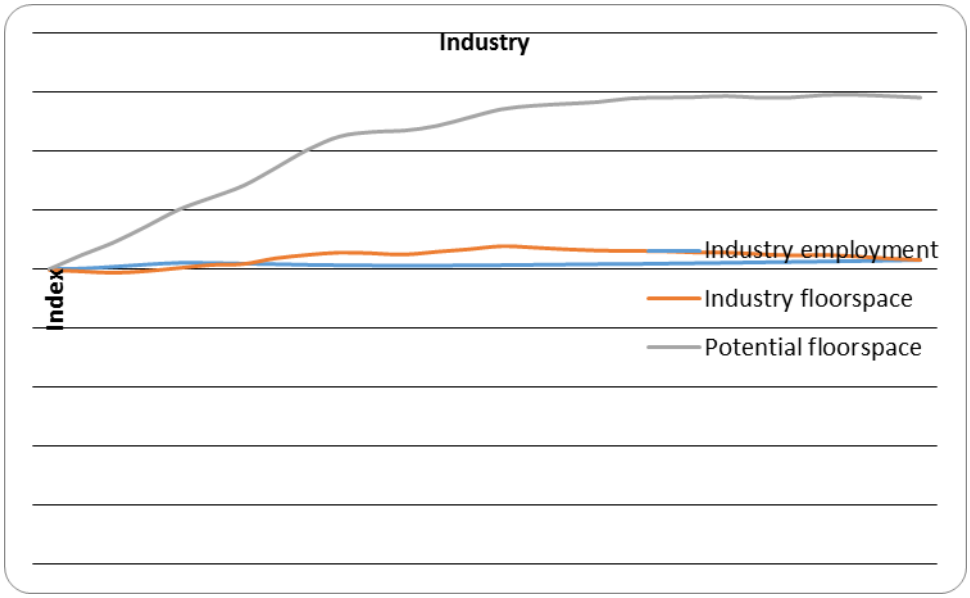

Figure 11-4 Growth in Industry floor and total industry employment (Test FN)

11.1.15 Figure 11-5 shows the forecasts for warehouse floorspace and warehouse based employment. The economic scenario suggests around a 10% increase in the number of warehouse-related jobs in total. In contrast the permissible development implies that there is potential for around a 40% increase in warehouse floorspace, if all of the permissible development was taken up. The model has been calibrated so that the amount built is consistent with the growth in warehouse based employment.

Figure 11-5 Growth in Warehouse floor and total warehouse employment (Test FN)

11.1.16 Figure 11-6 shows the forecasts for the combined leisure and hotel floorspace and associated employment. The economic scenario suggests an increase of between 15% and 20% increase in the number of leisure-related jobs in total. In contrast the permissible development implies that there is potential for only a 7% increase in leisure floorspace, if all of the permissible development was taken up. The model has been calibrated so that all of the viable leisure permissible floorspace is taken up.

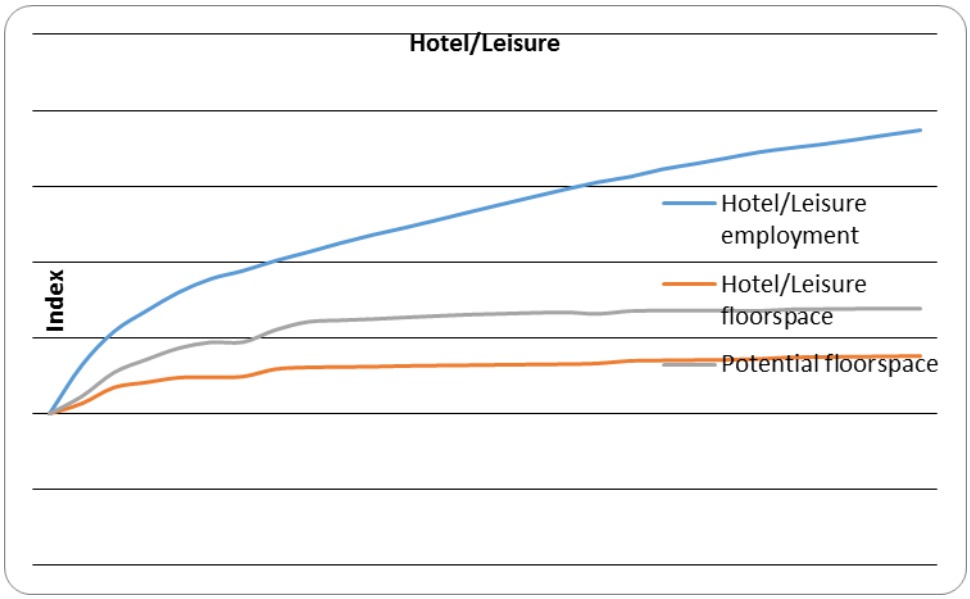

Figure 11-6 Growth in Hospitality floor and total hospitality employment (Test FN)

12 CONCLUSION

12.1 Conclusion

12.1.1 Like any good modelling project, this one has drawn extensively on previous experience and made use of ideas and inputs from other recent work, especially recently published research, whilst at the same time it has generated a range of new ideas. Some of these ideas have been pursued within the project the treatment of persons working at home); some are still being pursued, particularly in the context of the work on the variable productivity model; and others are effectively out of scope for the time being because of time and resource limitations.

12.1.2 We believe that TELMoS14 keeps LATIS at the state of the art in land-use/economic transport interaction modelling at the national/regional scale, and that the forthcoming use of TELMoS14 will be valuable in informing decisions on land-use, transport and economic development proposals.

APPENDIX A MATHEMATICS OF THE TELMOS14 APPLICATION

A.1 Introduction

A.1.1 This section sets out the main equations of the DELTA sub-models used in TELMoS14 modelling. It includes the calculation of intermediate variables such as accessibility measures. It goes through the sub-models in the logical sequence in which they are carried out in each annual cycle, starting with the accessibility calculations that are carried out on the outputs of the transport model.

A.2 Notation

A.2.1 The general rule for the mathematical notation is that:

- upper case roman letters are used to represent quantities and other main variables of the model;
- lower case roman letters represent ratios;
- Greek letters represent coefficients, i.e. input values that usually describe some aspect of behaviour;
- subscripts indicate time and place;
- superscripts refer to different categories (e.g. different types of household);
- suffices in brackets are used to indicate temporary or transitory categories, e.g. those households of a particular type just arrived in the study area.

A.2.2 The upper case letters, subscripts and superscripts are meant to be used consistently throughout the mathematical documentation, and are defined below. Other notation is introduced as needed, and may be reused from one sub-model to another.

A.2.3 The main variables are:

A	accessibility
E	employment
F	floorspace
H	households
Q	quality
U	utility (of consumption)
V	utility (of location)

A.2.4 Subsets of these variables are identified by "postscripts" in brackets, e.g. H(M) for moving households.

A.2.5 The common subscripts are

i zone

p time period (one year)

t point in time.

A.2.6 Period *p* is the period from *t* to *t+1*. The following description of the model's workings in one year therefore describes the workings within period *p*, starting from the database for time *t* (and some inputs from earlier databases) and leading to the results which form the output database for time *t+1*.

A.3 Accessibility calculations by measure

A.3.1 The first stage in the accessibility calculations is carried out by program AC12. This is run in each year, whether or not it is a transport model year. It takes as input:

- matrices of generalised costs for different purposes, by mode, from the most recent transport model year;
- vectors of production and attraction weights, derived from the current TELMoS14 database;
- mode choice and destination choice coefficients. These are all input by purpose and mode.

A.3.2 These data and coefficients are used to calculate active (origin) and passive (destination) accessibility measures for each combination of purpose and weights defined in the accessibility definition file. The calculations are standard logsum forms. First an average generalised cost over modes is found using equations of the form (omitting year and purpose, for clarity):

$$g_{ij} = \frac{1}{-\lambda_{ij}^{M}} \ln \sum_{m} \exp\left(-\lambda_{ij}^{M} \cdot g_{ijm}\right)$$

where

g_{ijm} is the generalised cost from *i* to *j* by mode *m*;

$-\lambda_{ij}^{M}$ is a value for the mode choice coefficient over the distance from *i* to *j*.

A.3.3 The mode choice coefficient is itself calculated as a function of the distance *i* to *j*:

$$\lambda_{ij}^{M} = \Lambda_{REF}^{M} \left(\frac{d_{ij}}{d_{REF}} \right)^{-\alpha}$$

where in turn

Λ_{REF}^{M} is the value of the coefficient at an arbitrary reference distance d_{REF};

d_{ij} is the distance *i* to *j*, and

$-\alpha$ is a coefficient defining the rate at which the coefficient decreases with increasing distance.

A.3.4 Then active accessibilities are calculated using the form (with the purpose and measure superscripts omitted for clarity)

$$A_i^m = \frac{1}{-\lambda^{mD}}\left(\ln\left\{\sum_j W_j^m \exp\left(-\lambda^{mD} g_{ij}^p\right)\right\} - K^{mJ}\right)$$

where

$-\lambda^{mD}$ is the destination choice coefficient

W_j^m is the relevant weight for zone *j*, assembled from the relevant variables in the current land-use database. These are defined for each accessibility measure as show the Table 8.1 above, and

K^{mJ} is defined as

$$K^{mJ} = \ln \sum_j W_j^{base\_year}$$

A.3.5 Similarly passive accessibilities are found using equations of the form

$$A_j^m = \frac{1}{-\lambda^{mD}}\left(\ln\left\{\sum_i W_i^m \exp\left(-\lambda^{mD} g_{ij}^p\right)\right\} - K^{mI}\right)$$

where

$-\lambda^{mD}$ is the destination choice coefficient

W_i^m is the relevant weight for zone *i.* These are defined for each accessibility measure as show the Table 8.1 above, and

$$K^{mI} = \ln \sum_i W_i^{base\_year} \quad .$$

A.4 Accessibility calculations by activity

A.4.1 The second stage in the accessibility calculations is carried out by program IA12. This finds values of zonal accessibility for each activity from the various accessibility measures calculated by AC12. The TELMoS14 activities are separated into two groups for this purpose; household activities and employment activities.

A.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 typically expected to make. These are all-mode (total) rates, and to ensure comparability of accessibility they do not vary spatially.

A.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 or the opportunities to which those trips would be made (e.g. the socio-economic level of the jobs of interest).

A.4.4 The inputs defining household accessibilities in terms of different measures of more specific accessibilities are the same in all years. These values are recalculated in each year, whether or not it is a transport model year.

A.4.5 Accessibility measures for employment activities are based on varying combinations of

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

A.4.6 The outputs of these calculations are the accessibilities of each zone for each activity (i.e. values of A_{ti}^{h} for each household type *h*, and A_{ti}^{s} for each employment type *s*.) As explained above, these are in generalised cost units; they are logsum values so negatives, though counter-intuitive, are possible. (Since the zonal accessibilities are used entirely by comparing absolute values, negatives do not cause any logical or computational problems within the model.)

A.5 REM: transport costs per unit of trade

A.5.1 The accessibility calculations described above are based on generalised costs of transport, measured in minutes, per unit of transport demand – for passenger travel, per person, and for goods movement, per vehicle. Program AC12 uses values of time to convert these costs into money costs for use in the REM. Program IT12 converts these costs per unit of transport demand into costs per unit of trade, i.e. into transport costs (in £M) per £M of trade.

A.5.2 To do this, we specify the number of goods-vehicle and person movements needed to deliver one unit of trade from producer to consumer. These figures include business travel as well as goods movement, and also private trips to shop in the final stage from retailers to households.

A.6 REM: macrozone accessibilities

A.6.1 Program AA12 calculates accessibility measures by macrozone and sector, as input to the investment model. This program does not require any inputs of its own: the coefficients it uses in calculating accessibilities are the distribution coefficients of the trade model.

A.6.2 The macrozone accessibilities output by AA12 are "size" measures rather than "cost" measures (of the zonal accessibilities defined above). Hence,

- the values must always be positive;
- larger (more positive) values indicate better accessibilities.

A.6.3 The equations are of the form

$$A_{ta}^{s} = \sum_{z} W_{tz}^{s} . \exp(-\lambda_{t}^{s} . c_{Tij}^{s})$$

where

A_{ta}^{s} is the accessibility of macrozone *a* for sector *s* (i.e. accessibility to the demand for sector *s* at time *t*);

W_{tz}^{s} is the demand for the outputs of sector *s* in macrozone *z* at time *t* (from the trade and production model);

c_{taz}^{s} is the cost of delivering one unit of *s* from *a* to *z* at time *t* (from the calculations described above); and

$-\lambda_{t}^{s}$ is the distribution coefficient of the trade model for *s* at time *t* (calibrated as part of the work on the trade and production model),

A.7 REM: investment

A.7.1 The inputs to the investment model are as follows:

- the depreciation rate, i.e. the proportion of capacity in each sector which expires in each year;
- the rate of investment in each sector (including reinvestment to replace depreciating assets);
- the sensitivities to accessibility and cost change in allocating total investment to macrozones.

A.7.2 Depreciation is assumed to be uniform, so (ignoring the possibility of exogenous inputs)

$$K(S)_{pa}^{s} = K_{ta}^{s} . \left(1 - d_{p}^{s}\right)$$

where:

d_{p}^{s} is the depreciation rate for sector *s* in the current period *p;*

K_{ta}^{s} is the existing capacity of sector *s* in macrozone *a* at time *t*;

$K(S)_{pa}^{s}$ is the surviving capacity carried forward to the next period.

A.7.3 The investment distribution models are of the form

$$K(N)^s_{pa} = K(N)^s_{p*} \frac{K^s_{ta} \cdot \left(\frac{A^s_{ta}}{A^s_{(tB)a}} \right)^{\lambda(A)^s_p} \left(\frac{c^s_{ta}}{c^s_{(tB)a}} \right)^{\lambda(c)^s_p}}{\sum_a \left[K^s_{ta} \cdot \left(\frac{A^s_{ta}}{A^s_{(tB)a}} \right)^{\lambda(A)^s_p} \left(\frac{c^s_{ta}}{c^s_{(tB)a}} \right)^{\lambda(c)^s_p} \right]}$$

where

$K(N)^s_{pa}$ is the additional capacity of sector *s* in macrozone *a* resulting from investment during period *p*;

$K(N)^s_{p*}$ is the total additional capacity of sector *s* resulting from investment in the modelled economy during period *p* (i.e. the product of the rate of total investment and the previous capacity);

A^s_{ta} is the accessibility of macrozone *a* for sector *s* at time *t*;

$A^s_{(tB)a}$ is the accessibility of macrozone *a* for sector *s* at the earlier time (*tB)* (so the model is responding to the change in accessibility from *tB* to *t*);

c^s_{ta} is the location cost of producing outputs of sector *s* in macrozone *a* at time *t*;

$c^s_{(tB)a}$ is the location cost of producing outputs of sector *s* in macrozone *a* at time (*tB)* (so the model is responding to the change in costs from *tB* to *t*);

$\lambda(A)^s_p$, $\lambda(C)^s_p$ are the coefficients for the distribution of investment. These can vary over time though in practice they are usually held constant throughout the forecast period.

A.7.4 In a scenario-matching Base test the resulting capacity for the next period is then the surviving capacity plus new investment, i.e.

$$K^s_{(t+1)a} = K(S)^s_{pa} + K(N)^s_{pa}$$

A.7.5 In an Alternative test it is the same plus the adjustments worked out by the trade model in order to batch the given scenario in the Base test, i.e.

$$K^s_{(t+1)a} = K(S)^s_{pa} + K(N)^s_{pa} + K(BA)^s_{pa}$$

A.7.6 The net change in capacity for any one macrozone in one year therefore depends whether the new investment is greater or less than the depreciation of its previous capacity. This will depend on

- the rate of total investment relative to deprecation, which is part of the given scenario (if any industry is declining rapidly in total, it is likely to decline in all macrozones, even ones which are improving in both accessibility and cost);
- the macrozone's changes in accessibility and cost, relative to the average changes in these (an macrozone which is becoming relatively less

accessible, as a result of network improvements elsewhere, may lose investment even in growing sectors).

A.8 REM: trade and production

A.8.1 The trade and production model is a fairly conventional spatial input-output model in which the key equations are of the form

$$T^s_{(t+1)ij} = Y^s_{(t+1)\,j}\,\frac{K^s_{(t+1)i}.\exp(-\lambda^s_t.c^s_{Tij})}{\sum_i K^s_{(t+1)i}.\exp(-\lambda^s_t.c^s_{Tij})}$$

where

$T^s_{(t+1)ij}$ is the trade in *s* from *i* to j at time *t+1*;

$Y^s_{(t+1)\,j}$ is the total demand for *s* at *j*;

$K^s_{(t+1)i}$ is the capacity of zone *i* to produce *s* at time *t+1;*

$-\lambda^s_t$ is the distribution coefficient for *s* at time *t*;

c^s_{Tij} is the cost of transporting one unit of *s* from *i* to *j* in the most recent transport model year *T*.

A.8.2 The total demand $Y^s_{(t+1)\,j}$ is the sum of final demand, defined as part of the economic scenario, and intermediate demand, calculated by applying technical coefficients to the total production, i.e.

$$Y^s_{(t+1)\,j} = Y(F)^s_{(t+1)\,j} + \sum_r a^{sr}_p.P^r_{(t+1)\,j}$$

where the production is the sum of the trades being supplied from each macrozone, i.e.

$$P^r_{(t+1)i} = \sum_j T^r_{(t+1)ij}$$

A.8.3 The trade quantities on the right-hand side of this last equation are the results of the trade calculation in A.8.1, so these equations therefore have to be solved iteratively. The final demand component is fixed as

$$Y(F)^s_{(t+1)\,j} = C^s_{tj} + G^s_{pj} + X^{\,s}_{pj}$$

where

C^s_{tj} is households' consumption expenditure on goods and services from sector *s* consumers in *j* at time *t;* this is a fraction of the total income of households resident in macrozone *j*, the fraction for each sector *s* being input as part of the scenario;

G^s_{pj} is government and other final demand, input exogenously; and

$X^{\,s}_{pj}$ is export demand, input exogenously and allocated to

macrozones *j* in proportion to their capacity K^{s}_{tj}

A.8.4 Expected employment by sector and socio-economic level is calculated as a simple multiple of output, the multiples being defined as part of the scenario. This is used in the calculations of floorspace demand (see A.8.5) and labour demand (see A.19).

A.8.5 In a Base test there is a further refinement in that the capacity terms $K^{s}_{(t+1)i}$ are iteratively adjusted to ensure that the employment calculated from the production matches the given targets to within a user-defined tolerance. This is done by using $K^{s}_{(t+1)i} + K(BA)^{s}_{(t+1)i}$ rather than just $K^{s}_{(t+1)i}$ in the trade model above, with the values of $K(BA)^{s}_{(t+1)i}$ being adjusted so that the targets are matched. The values of $K(BA)^{s}_{(t+1)i}$ are output in the Base test and used as adjustments to the capacity model in all Alternative tests that pivot around that Base (see A.7.5).

A.9 Development model

A.9.1 The model is formulated so as to estimate the amount of floorspace that developers will seek to build as a fraction of the existing stock. This fraction is calculated as a constant multiplied by a function of the average rent.

A.9.2 The distribution of development to zones is forecast by a logit model of the form

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

where

$F(N)^{du}_{pi}$ the amount of new floorspace of type *u* in zone *i* started in period *p*,

$F(C)^{u}_{p*}$ is the (constrained) quantity of new floorspace type u to be started in period p,

$F(PV)^{du}_{pi}$ the current permissible-and-viable development of process *du* in zone *I*,

r^{u}_{ti} is the rent in zone *i* for space category *u* in time period *t*,

c^{du}_{pi} is the cost of developing (*d*,*s*) at *i* in the present period *p* (in the same units as rents;

γ^{u}_{p} is the sensitivity of development location to expected profitability.

A.9.3 The program then checks that the constraints on development are satisfied, i.e. that

$$F^{ud}_{pi} \quad \leq \quad F(\max)^{ud}_{pi}$$

A.9.4 Any development in excess of the constraint is subtracted and reallocated to unconstrained zones if permissible viable floorspace is available in other zones.

A.9.5 The model can allow for the likelihood that developers will tend to maintain a "land bank" of unused permissible development, since this represents their "stock" for future activity. This effect slows down the total quantity of development if the supply of "permissible development" is below a certain level.

A.9.6 The maximum permissible viable floorspace $F(\max)_{pi}^{ud}$ will initially be set up as an exogenous policy input. A future, planned, enhancement relating to the modelling of redevelopment and intensification will refine this so that it defines the permissible rate at which the stock might be increased by infill or redevelopment at higher densities.

A.10 Transition model (i) household activities

A.10.1 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.10.2 Similar formulae are used for the other changes.

A.10.3 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.10.4 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.11 Transition model (ii) employment activities

A.11.1 Changes in employment activities are driven by the outputs of the regional economic model. The changes in employment processed in MT12 relate to nominal employment which determines the demand for space in the location sub-model – i.e. the expected number of workers for which employers will rent space. Actual employment, which may differ from nominal employment, is separately calculated in the employment sub-model. The rates of change in each sector's nominal employment are calculated by MT12 from the notional employment calculated by the REM.

A.11.2 In addition to the net change, a proportion of the existing employment in each sector and each zone is defined as mobile in each one-year period. Like its household equivalent, this is important to representing the changes in occupancy of the second-hand floorspace stock.

A.11.3 The model first finds the mobile and immobile components of existing employment:

$$E(M)^{s}_{pi} = E^{s}_{ti}.m^{s}_{p}$$

$$E(I)^{s}_{pi} = E^{s}_{ti}.(1-m^{s}_{p})$$

where

E^{s}_{ti} is total employment activity *s* during time period *p* in zone *i* ;

$E(M)^{s}_{pi}$ and $E(I)^{s}_{pi}$ are mobile and immobile employment;

m_p^s is a mobility rate.

A.11.4 The new total employment by macrozone $E(N)^{s}_{pa}$ is found from the previous employment (E^{s}_{ti} , summed over zones in macrozone *a*) scaled by the change in expected employment generated by the REM, $E(REM)^{S}_{(t+1)a}$:

$$E(N)^{s}_{pa} = \left\{ \sum_{i \in a} E^{s}_{ti} \right\} \left\{ \frac{E(REM)^{S}_{(t+1)a}}{E(REM)^{S}_{ta}} \right\}$$

where *S* is the REM sector (or set of sectors) corresponding to zonal activity *s* (see Table 6-2).

A.11.5 The pool, mobile and immobile qualities within each macrozone *a* are then adjusted to match this new total of nominal employment.

A.12 Migration model

A.12.1 The migration model software is designed to handle two streams of migration, but only one is in use.

A.12.2 The modelled migration stream is influenced by

- the total number of households in the origin macrozone,
- the "push" factor for the origin macrozone,
- the deterrence factor of the origin-to-destination distance,
- the total number of households in the destination macrozone,
- the "pull" factor for the destination macrozone,
- an overall scaling factor.

A.12.3 The 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 macrozone *a* to macrozone *z* during period *p* (before considering constraints);
H^{h}_{ta}	is the total number of households of type *h* in macrozone *a* at time *t*
$v(O)^{hs}_{pa}$	is the origin macrozone *a* push factor for stream *s* migration of households *h* in period *p*;
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}	total households of type *h* in macrozone *z* at time *t*;
$v(D)^{hs}_{pz}$	origin macrozone *z* pull factor for stream *s* migration of households *h* in period *p*;
s^{hs}_{p}	a scaling factor for overall level of migration of households *h* in period *p*.

A.12.4 This input takes a set of coefficients to weight the migration-influencing variables as "push" and "pull" factors. The "push" and "pull" variables are defined in section 10.3.

A.12.5 The $M(U)^{hs}_{paz}$ values are subtracted from the pool and mobile households in the origin macrozone ($H(P)^{k}_{pa}$ and $H(M)^{h}_{pi}$) and added to the pool households in the destination macrozone *z*, $H(P)^{k}_{pz}$ (i.e. those with no prior location within the macrozone).

A.13 Household income

A.13.1 MI12 calculates income per household by type and zone as a simple linear function ie

- a constant income per household, **plus**
- an additional income per worker in the household.

A.13.2 Both the constant income per household by type and the additional income per worker are defined as part of the economic scenario and input for each household type in each year.

A.13.3 For household activities with zero workers, the output income per household will be the minimum value.

A.14 Car ownership

A.14.1 The car ownership model is an adapted version of that used in the Department for Transport's NATCOP model. Car ownership is calculated as the probability of households of type *h* living in zone *i* in year *t+1* owning 0, 1, 2 or 3+ cars. This is calculated by first calculating the probability that such households own one or more cars; then the conditional probability that those car-owning households own two or more; and finally the conditional probability that the households owning two or more cars own three or more. The calculation of the probabilities is of the form

$$p^{h}_{(t+1)i(1+)} = \frac{s^{h}_{i(1+)}}{1+\left[\frac{s^{h}_{i(1+)} - p^{h}_{ti(1+)}}{p^{h}_{ti(1+)}}\right]\exp\left(-\Delta X^{h}_{pi(1+)}\right)}$$

where this particular equation is for the probability of owning one or more cars (1+) and

- $s^{h}_{i(1+)}$ is the estimated saturation level for this car ownership level for household type *h* in area *i*;
- $p^{h}_{ti(1+)}$ is the equivalent probability of car ownership in the previous year;
- $\Delta X^{h}_{pi(1+)}$ is a predictor calculated as a linear function of the changes in income and other variables over the preceding year.

A.14.2 The effect of this model is that the probability will increase asymptotically towards the saturation level as the variables having a positive effect increase. The effect of an increase in incomes (for example) is therefore much greater for a household type/zone/year where car ownership is very low than for one where it is close to saturation.

A.14.3 One complication with detailed household types and small zones is that the base data can show car ownership proportions above the saturation levels. These proportions are assumed not to change.

A.14.4 The variables included in $\Delta X^{h}_{pi(1+)}$ are documented in 10.5.

A.15 Location model: household location

A.15.1 The location sub-model is both the "location and relocation sub-model", and the "property market sub-model". In the general design, mobile activities respond to changes in five variables:

- quantity of housing (from the development model, above);
- accessibility (from the accessibility calculations, above)
- quality of housing (from the quality model, below)
- floorspace per household (from the household location model); and
- the cost or utility of consumption, i.e. of spending income on housing, travel, and other goods and services (calculated within the location sub-model).

A.15.2 The location model involves an explicit model of relocation (identifying where from and where to) for appropriate households. This includes distance as a deterrent factor, and works across macrozone boundaries as well as within macrozones. The task for the residential location model is

- to locate $H(P)^{h}_{pa}$, the "pool" of unlocated households type *h* to be located in macrozone *a, and*

- to relocate $H(M)^h_{po}$, the mobile households of type *h* initially located in zone *o*.

A.15.3 The inputs to the household location model consist of

- household incomes, which are part of the economic/demographic scenario;
- coefficients of the expenditure function;
- coefficients of the location model itself.

A.15.4 The timelags of the location model are also an important aspect of modelled behaviour.

A.15.5 The number of households located is the sum of those locating from the pool and from the mobile sets:

$$H(L)^h_{pi} = H(LM)^h_{pi} + H(LP)^h_{pi}$$

A.15.6 The number of mobile households located is the sum of all the relocation movements, i.e. those locating from the pool and from the mobile sets:

$$H(LM)^h_{pi} = \sum_o H(LMR)^h_{poi} = \sum_o H(M)^h_{po} \left\{ \frac{H(XA)^h_{pi} . \exp(\Delta V^h_{pi}) . d^h_{poi}}{\sum_i H(XA)^h_{pi} . \exp(\Delta V^h_{pi}) . d^h_{poi}} \right\}$$

A.15.7 The number of pool households located is a proportion of the pool for the macrozone:

$$H(LP)^h_{p(i \in a)} = H(P)^h_{pa} \cdot \frac{H(XA)^h_{pi} \cdot \exp(\Delta V^h_{pi})}{\sum_{i \in a} H(XA)^h_{pi} \cdot \exp(\Delta V^h_{pi})}$$

where

$H(L)^h_{pi}$ is the number of households type *h* located at zone *i* during period *p*;

$H(P)^h_{pa}$ is the number of such households in the "pool" to be located within macrozone *a*;

$H(M)^h_{po}$ is the number of mobile households which may relocate from zone *o*;

d^h_{poi} is a deterrence function for households type h relocating from o to i in period p;

$H(XA)^h_{pi}$ is the number of expected occupiers at *i*, reflecting the stock of vacant floorspace, the characteristics of newly-completed floorspace and the number of mobile households;

ΔV^h_{pi} is the change in the utility of location of zone *i* for households *h* moving in period *p*.

A.15.8 The distance-deterrence function d^h_{poi} is a negative logistic function of the distance between o and i.

A.15.9 The change in utility of location is calculated as:

$$\Delta V^{h}_{pi} = \theta^{hC}_{p} (a^{hO}_{pi} - a^{hO}_{(tB(U,h))i}) \quad + \theta^{hA}_{p} (A^{h}_{(tA(A,h))i} - A^{h}_{(tB(A,h))i})$$
$$+ \theta^{hQ}_{p} (Q^{h}_{(tA(Q,h))i} - Q^{h}_{(tB(Q,h))i}) + \theta^{hH}_{p} (\ln\left[a^{hH}_{pi} - \min(a^{hH}_{p}) \right] - \ln\left[a^{hH}_{tB(U,h))i} - \min(a^{hH}_{p}) \right])$$

where:

a^{hO}_{tz}	consumption of other goods and services per household of type *h* located in zone *z* at time *t*;
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);
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.15.10 One refinement in the present model is that the θ^{hC}_{p} is positive:

- when utility of location changes in response to a change in rent, the change in expenditure on other goods and services will be roughly the opposite of the change in expenditure on housing;
- when utility of location changes in response to a change in incomes, the effect will be quite different: expenditure on other goods and services will have a positive impact on the utility of location.

A.15.11 Floorspace per household is found as

$$a^{hH}_{pi} = q^{hH}_{i} \left[\min(a^{hH}_{p}) + \frac{\alpha^{hH}_{p} (y^{h}_{pi} - \min(a^{hH}_{p}) \cdot r^{H}_{pi} - \min(a^{hO}_{p}))}{r^{H}_{pi}} \right]$$

where the additional terms are:

α^{hH}_{p}	the propensity of households type *h* to spend discretionary income on housing;
y^{h}_{pi}	is income (after taxes and benefits);
$\min(a^{hO}_{p})$	is minimum expenditure on other goods and services (i.e. everything except housing);
r^{H}_{pi}	is the current rent per unit of housing; and
q^{hH}_{i}	is a factor calculated in the base year to reconcile the expected demand for floorspace, estimated from this equation and the base year numbers of households, with the occupied housing stock in that year. This is assumed constant over time.

A.15.12 The location model is solved iteratively by adjusting the rents r^H_{pi} until the total floorspace occupied by the locating households, plus floorspace left vacant (which is itself a function of the rent), equals the available floorspace (i.e. new floorspace plus available second-hand floorspace).

A.15.13 Note that the underlying assumptions of the model are that in the absence of changes to floorspace, accessibility or other supply/locational characteristics, then pool households of each type will tend to locate in proportion to the existing distribution of households of that type. The behaviour of mobile households is more complex but is such that they will tend to show a net no-change effect if none of the other variables is changing.

A.16 Location model: employment location

A.16.1 The employment location model is similar to but simpler than the residential location model. Pool employment of sector *s* is located by:

$$E(LP)^s_{p(i\in a)} = E(P)^s_{pa} \cdot \frac{E^s_{ti} \cdot \left(\frac{F(A)^u_{pi}}{F(O)^u_{ti}} \right) \cdot \exp(\Delta V^s_{pi})}{\sum_{i\in a} E^s_{ti} \cdot \left(\frac{F(A)^u_{pi}}{F(O)^u_{ti}} \right) \cdot \exp(\Delta V^s_{pi})}$$

and "mobile" activities are located by:

$$E(LM)^s_{p(i\in a)} = \left[\sum_{i\in a} E(M)^s_{pi} \right] \cdot \left\{ \frac{E(M)^s_{pi} \cdot \left(\frac{F(A)^u_{pi}}{F(M)^u_{pi}} \right) \cdot \exp(\Delta V^s_{pi})}{\sum_{i\in a} E(M)^s_{pi} \cdot \left(\frac{F(A)^u_{pi}}{F(M)^u_{pi}} \right) \cdot \exp(\Delta V^s_{pi})} \right\}$$

where

$E(LP)^s_{pi}$ is the employment sector s located from the pool to zone i;

$E(P)^s_{p*}$ is the total "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) which may move and vacate it.

A.16.2 The change in utility of location is defined as

$$\Delta V^s_{pi} = \theta^{sU}_p \left(c^s_{pi} - c^s_{(tB(U))i} \right) + \theta^{sA}_p \left(A^s_{(tA(A))i} - A^s_{(tB(A))i} \right)$$

A.16.3 This is similar to the equivalent term for household location except that floorspace per worker and floorspace quality are excluded from the utility equation. Cost of location per job is floorspace per worker times cost per unit floorspace (rent plus other costs). Floorspace per worker is calculated as the previous year's value adjusted by an elasticity with respect to rent.

A.17 Location model: housing and floorspace vacancy changes

A.17.1 The proportion of floorspace remaining vacant changes in response to changes in rent - at high rents, floorspace is less likely to remain vacant. Note that the elasticity is actually that of occupied floorspace with respect to rent, so it is a positive value (higher rent will lead to more floorspace being let).

A.18 Location model: other employment

A.18.1 Other employment is located by scaling the previous employment up or down to match the outputs from the REM.

A.19 Employment status and persons model

A.19.1 The employment status sub-model has four main functions:

- to convert the located employment by zone and sector into employment by zone and socio-economic group, i.e. to calculate the demand for labour in terms which can be related to the supply of labour (i.e. households);
- to convert the located households by type and zone into numbers of children, working-age and retired persons;
- to adjust the numbers of working-age persons in work to match the current demand for labour (and hence to adjust the numbers of working-age persons **not** in work);
- to update the travel-to-work matrices used within the land-use model in line with the changes in labour demand and supply.

A.19.2 The changes in total employment by activity and macrozone based on outputs from the regional economic model.

A.19.3 The allocation of jobs to zones is proportional to the distribution of "nominal" or "expected" jobs resulting from the location model.

A.19.4 The numbers of persons in the three broad age groups are found by adjusting the previous values of persons per household so as to match average values specified as part of the demographic scenario. This allows for change over time in ratios such as children per household, whilst retaining differences between zones.

A.19.5 The changes in travel-to-work and in whether residents are in work or not is a process of adjusting the travel-to-work matrices in response to the changes in labour demand and labour supply, and allowing the labour supply to adjust (i.e. individuals gain or lose employment) so as to match the labour demand exactly. Note that in order to ensure that forecasts conform to the given employment scenario, the model assumes that all of the forecast jobs must be filled.

A.20 Housing quality model

A.20.1 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.20.2 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.20.3 The first step is

$$Q(E)^s_{pi} = \alpha^s_p + \beta^s_p . \bar{y}_{ti}$$

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.20.4 The second step is

$$Q^s_{(t+1)i} = Q(D)^s_{pi} . \left(1 - f^s_p\right) + Q(E)^s_{pi} . f^s_p$$

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.

A.21 Conclusion

A.21.1 At this point, the model has forecast all the land-use/economic changes for the current forecast year, and written the resulting database files. Then

- if the current year is is a transport model year, and a full LUTI run is being carried out, the model simply stops: it is then for the user to run the interface programs which produce the output to be sent to TMfS14. After files have been received back from TMfS14, the sequence will be restarted with the accessibility calculations (Section A3).

- if the current year is a transport model year but the current forecast is not a full LUTI run, sequence will automatically continue with the accessibility values using previously supplied transport model outputs.
- if the current year is not a transport model year, the sequence continues with the accessibility calculations using recent generalised cost data from the most recent transport model year).

A.21.2 In the final year of the forecast the sequence will continue with the accessibility changes, run to the last program of the year, then stop.

APPENDIX B ECONOMIC AND DEMOGRAPHIC SCENARIOS

B.1 Regional Constraints

Section 6 described the approach by which TELMoS14's economic scenario is constrained at the regional level.

B.1.1 Figure B-1 shows a comparison of the independent employment forecast for each region and TELMoS's forecast employment growth.

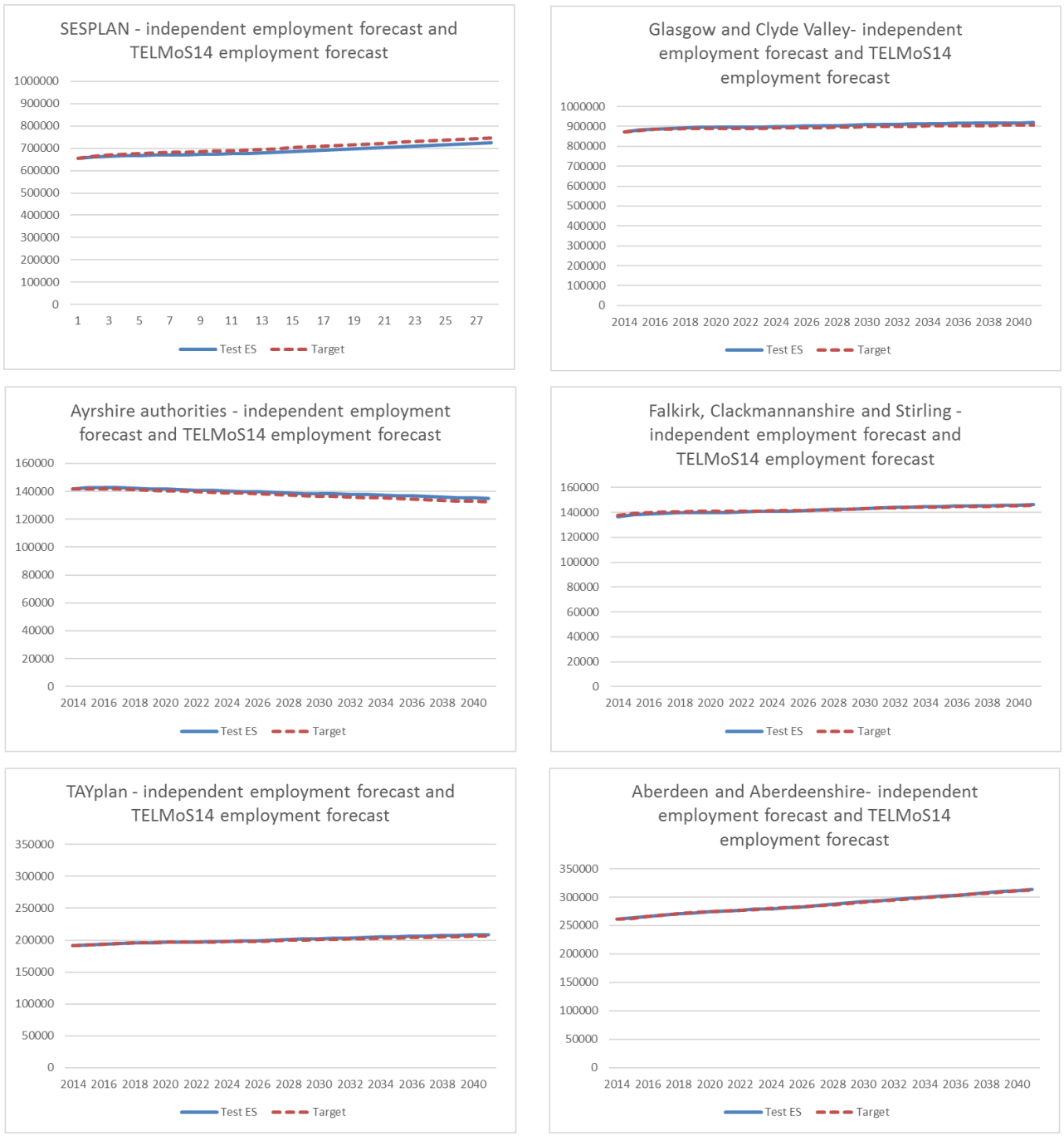

Figure B-1 Comparison of Target and Forecast employment by region

B.1.2 Figure B-2 shows a comparison of the NRS 2012 population forecast and TELMoS14's national forecast. In this comparison the NRS forecasts have been aggregated to the three age-groups that are modelled in TELMoS, children, people of working age and retired people.

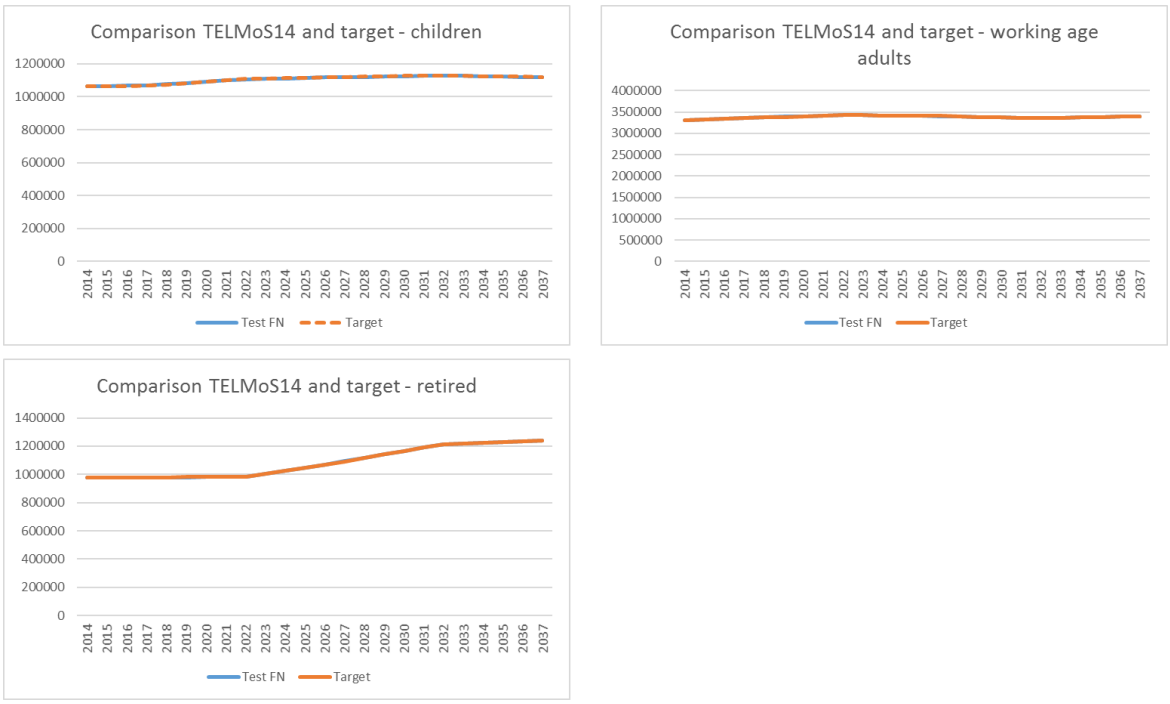

Figure B-2 Comparison of TELMoS' demographic forecast and the NRS 2012 based forecast.

B.1.3 Figure B-3 shows a comparison of the NRS 2012 household projections and TELMoS14's forecasts of household change. In this comparison the NRS forecasts have been converted to the eight household groups that are modelled in TELMoS14. The Figure shows a consistency between the independent (NRS) forecasts and TELMoS14's forecast.

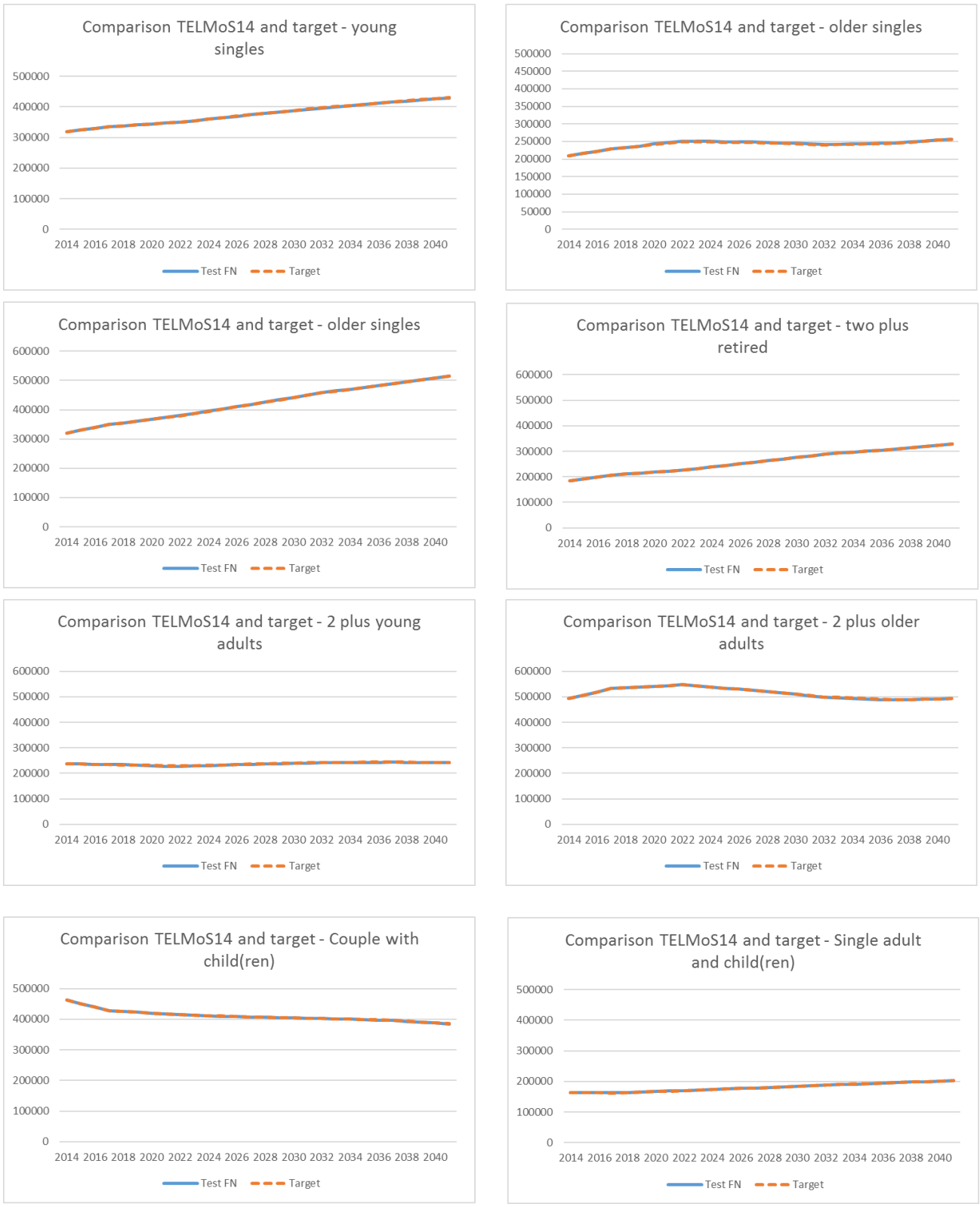

Figure B-3 Comparison of TELMoS' household forecast and the NRS 2012 based forecast.

APPENDIX C LAND USE PLANNING INPUTS

C.1.1 Tables C1 to C8 show the planning policy inputs for each of the eight modelled land uses at Local Authority level. These inputs are derived from the APPI2014 exercise described in Chapter 7.

Table C-1 Residential Planning Inputs (floorspace and dwelling units)

	Residential floorspace (m^2, rounded to nearest $100m^2$)						Dwellings (rounded to nearest 10)				
	2015-2017	**2018-2022**	**2023-2027**	**2028-2032**	**2033-2037**		**2015-2017**	**2018-2022**	**2023-2027**	**2028-2032**	**2033-2037**
Dumfries and Galloway	195400	601700	344100	168400	77600		1640	5030	2860	1390	650
Scottish Borders	151600	346400	56700	44100	26500		1320	3010	490	380	230
East Lothian	240000	652500	220600	63600	0		2350	6320	2220	620	0
Midlothian	218300	659300	523800	222700	0		2070	6270	4940	2060	0
City of Edinburgh	398000	823100	436700	212600	150500		4830	10090	5710	3050	2140
West Lothian	250400	853300	645700	195700	0		2450	8270	6350	1950	0
South Lanarkshire	252900	785100	874500	389400	134700		2420	7300	8150	3670	1260
East Ayrshire	130600	291100	194500	47200	21200		1240	2750	1830	450	200
South Ayrshire	105400	421100	252800	106900	105200		980	3980	2220	830	810
North Ayrshire	104000	298200	256300	121900	0		990	2920	2530	1220	0
East Renfrewshire	90400	162800	101500	84200	40000		870	1600	1000	850	410
Glasgow City	669300	1115700	939300	811500	661600		8920	14580	12650	11350	9230
North Lanarkshire	350700	560000	409600	383800	383800		3620	5670	4110	3840	3840
Falkirk	158700	483500	257300	102100	66600		1550	4650	2430	980	630
East Dunbartonshire	106100	252500	57600	33000	0		1030	2470	580	290	0
Renfrewshire	111100	289800	393700	163200	75000		1170	2870	3990	1640	620

	Residential floorspace (m^2, rounded to nearest $100m^2$)						**Dwellings (rounded to nearest 10)**				
	2015-2017	**2018-2022**	**2023-2027**	**2028-2032**	**2033-2037**		**2015-2017**	**2018-2022**	**2023-2027**	**2028-2032**	**2033-2037**
Inverclyde	52000	185600	179200	111800	67100		560	2050	2030	1260	740
West Dunbartonshire	49700	245700	184500	49800	23600		570	2890	2160	610	300
Stirling	133600	238500	162100	134000	134000		1290	2390	1620	1340	1340
Clackmannanshire	103600	243300	148300	92700	37100		980	2310	1400	860	340
Fife	514200	1584000	1017200	179500	313000		4870	14800	9360	1780	3340
Perth and Kinross	302500	723600	524900	218800	117600		2530	6030	4320	1730	910
Dundee City	228800	406700	159900	110500	0		2530	4640	1810	1200	0
Angus	85700	163300	83800	34900	0		780	1510	780	330	0
Aberdeenshire	597100	1388600	789600	318100	176300		4680	10860	6210	2510	1410
Aberdeen City	434000	976000	746200	561600	425800		4280	8540	6350	4520	3410
Moray	140100	406700	271200	0	0		1110	3150	2090	0	0
Argyll and Bute	145800	293900	117300	0	0		1180	2370	950	0	0
Na h-Eileanan an Iar	35400	51600	24100	0	0		260	380	180	0	0
Highland	104100	184400	144600	153800	49400		770	1360	1060	1130	370
Orkney Islands	80400	131200	44400	15500	15500		590	970	330	110	110
Shetland Islands	39700	29300	16000	0	0		300	220	120	0	0
Scotland	6579600	15848500	10578000	5131300	3102100		64730	152250	102830	51950	32290

Table C-2 Retail Planning Inputs by local authority macrozone ('000s sq metres)

	2015-2017	2018-2022	2023-2027	2028-2032	2033-2037
Dumfries and Galloway	12400	29500	28800	10400	0
Scottish Borders	0	0	0	0	0
East Lothian	4600	3800	1500	0	0
Midlothian	16000	27300	12900	0	0
City of Edinburgh	119300	94600	15500	0	0
West Lothian	6500	8100	8100	4900	0
South Lanarkshire	29700	20100	2300	0	0
East Ayrshire	600	1100	0	0	0
South Ayrshire	8500	7900	1600	0	0
North Ayrshire	500	100	0	0	0
East Renfrewshire	8600	10000	4000	1900	700
Glasgow City	50800	33300	0	0	0
North Lanarkshire	0	0	0	0	0
Falkirk	151600	193200	191500	76500	0
East Dunbartonshire	0	0	0	0	0
Renfrewshire	34400	45800	16300	0	0
Inverclyde	24900	8800	8800	7000	0
West Dunbartonshire	25100	16500	1900	0	0
Stirling	21400	20000	5100	0	0
Clackmannanshire	3500	3200	2100	0	0
Fife	0	0	0	0	0
Perth and Kinross	33900	27100	4500	0	0
Dundee City	0	0	0	0	0
Angus	27400	39100	20400	0	0
Aberdeenshire	100	0	0	0	0
Aberdeen City	57200	188300	165700	41200	0
Moray	0	0	0	0	0
Argyll and Bute	7800	7500	5000	0	0
Na h-Eileanan an Iar	1000	500	0	0	0
Highland	23100	24600	9200	4800	3500
Orkney Islands	0	0	0	0	0
Shetland Islands	700	0	0	0	0
Scotland	669600	810400	505200	146700	4200

Table C-3 Office (m^2 floorspace, rounded to nearest $100m^2$)

	2015-2017	2018-2022	2023-2027	2028-2032	2033-2037
Dumfries and Galloway	82900	414300	400500	138100	0
Scottish Borders	52600	127900	40400	3400	0
East Lothian	15600	64000	29400	0	0
Midlothian	46000	201500	147100	0	0
City of Edinburgh	429700	1094200	532800	0	0
West Lothian	349700	1718800	801100	0	0
South Lanarkshire	10100	16800	6700	0	0
East Ayrshire	20700	45500	44100	15400	0
South Ayrshire	0	0	0	0	0
North Ayrshire	500	1200	300	0	0
East Renfrewshire	7000	31400	30300	26300	10500
Glasgow City	170200	354100	166100	100600	60300
North Lanarkshire	26200	130800	126700	110300	44100
Falkirk	76800	359100	168800	24200	0
East Dunbartonshire	46300	136400	18300	0	0
Renfrewshire	17000	53000	18800	0	0
Inverclyde	4500	18100	17600	15500	0
West Dunbartonshire	14800	67200	30800	0	0
Stirling	77100	269500	109100	0	0
Clackmannanshire	13400	54100	25100	0	0
Fife	21200	48300	28900	17300	10400
Perth and Kinross	22300	52200	34300	26500	10600
Dundee City	20000	100200	80200	0	0
Angus	7700	27500	20200	0	0
Aberdeenshire	96200	435100	267800	0	0
Aberdeen City	67000	75900	13400	0	0
Moray	18200	84000	80800	55100	0
Argyll and Bute	25700	113100	51500	0	0
Na h-Eileanan an Iar	5200	24800	11500	0	0

	2015-2017	2018-2022	2023-2027	2028-2032	2033-2037
Highland	7400	9100	8400	9400	4600
Orkney Islands	9800	41500	38000	31700	12700
Shetland Islands	3100	15500	15000	12900	5200
Scotland	1764900	6185100	3364000	586700	158400

Table C-4 industry (m^2 floorspace, rounded to nearest $100m^2$)

	2015-2017	2018-2022	2023-2027	2028-2032	2033-2037
Dumfries and Galloway	42400	212000	205000	70700	0
Scottish Borders	122900	303700	96400	8000	0
East Lothian	12000	22600	9300	0	0
Midlothian	15100	74100	52100	0	0
City of Edinburgh	0	0	0	0	0
West Lothian	66400	332200	155000	0	0
South Lanarkshire	27800	38500	13300	0	0
East Ayrshire	14100	68700	68600	27200	0
South Ayrshire	0	0	0	0	0
North Ayrshire	5400	2500	100	0	0
East Renfrewshire	12500	62400	60300	52000	41600
Glasgow City	60000	137500	101300	84300	45500
North Lanarkshire	120200	551200	532900	460100	184000
Falkirk	92400	478100	235800	13800	0
East Dunbartonshire	1400	3700	1300	0	0
Renfrewshire	8700	38400	16800	0	0
Inverclyde	9400	46900	44200	33300	0
West Dunbartonshire	25500	119700	54900	0	0
Stirling	77200	269500	109100	0	0
Clackmannanshire	51900	97100	36600	0	0
Fife	25100	60500	40200	21200	12700
Perth and Kinross	48100	99800	65700	52500	21000
Dundee City	16500	82500	66000	0	0
Angus	9300	44000	33800	0	0
Aberdeenshire	138600	648000	399800	0	0
Aberdeen City	17200	131400	127900	33700	0
Moray	41600	199200	192000	132400	0
Argyll and Bute	25500	106900	48300	0	0
Na h-Eileanan an Iar	12000	52900	24300	0	0
Highland	19100	26900	13900	15000	12600
Orkney Islands	27600	117300	107500	89100	35600
Shetland Islands	9200	41800	40400	35100	14100
Scotland	1155100	4470000	2952800	1128400	367100

Table C-5 warehouse (m^2 floorspace, rounded to nearest $100m^2$)

	2015-2017	2018-2022	2023-2027	2028-2032	2033-2037
Dumfries and Galloway	28700	143400	138600	47800	0
Scottish Borders	94100	221100	69200	5900	0
East Lothian	6000	9900	4000	0	0
Midlothian	5000	274400	226300	0	0
City of Edinburgh	57900	44500	0	0	0
West Lothian	21700	36100	14400	0	0
South Lanarkshire	21000	32900	11700	0	0
East Ayrshire	15200	56400	57200	24200	0
South Ayrshire	2700	6600	1800	0	0
North Ayrshire	900	2200	600	0	0
East Renfrewshire	13400	67000	64900	56500	45200
Glasgow City	39800	85400	68500	60200	27300
North Lanarkshire	63200	230200	224000	199000	79600
Falkirk	0	0	0	0	0
East Dunbartonshire	3100	3800	1100	0	0
Renfrewshire	14000	41700	17500	0	0
Inverclyde	4700	23500	22700	19600	0
West Dunbartonshire	17900	79700	36300	0	0
Stirling	61900	197700	86500	0	0
Clackmannanshire	126100	34600	8000	0	0
Fife	20600	37900	25200	16700	10000
Perth and Kinross	25000	20600	1400	0	0
Dundee City	23700	118600	94900	0	0
Angus	2600	1700	0	0	0
Aberdeenshire	120200	542100	325300	0	0
Aberdeen City	33200	186500	190400	27800	0
Moray	29100	130600	128100	95600	0
Argyll and Bute	22200	93400	42200	0	0
Na h-Eileanan an Iar	8800	39900	18400	0	0
Highland	18700	24900	16100	19000	15400
Orkney Islands	24600	104400	95700	79300	31700
Shetland Islands	6600	32900	31800	27400	11000
Scotland	932600	2924600	2022800	679000	220200

Table C-6 leisure and hotel (m^2 floorspace, rounded to nearest $100m^2$)

	2015-2017	2018-2022	2023-2027	2028-2032	2033-2037
Dumfries and Galloway	15500	25900	25900	10400	0
Scottish Borders	0	0	0	0	0
East Lothian	0	0	0	0	0
Midlothian	3800	6400	2500	0	0
City of Edinburgh	7500	0	0	0	0
West Lothian	200	300	300	200	0
South Lanarkshire	22000	36600	14700	0	0
East Ayrshire	0	0	0	0	0
South Ayrshire	0	0	0	0	0
North Ayrshire	2100	1400	0	0	0
East Renfrewshire	0	0	0	0	0
Glasgow City	116400	77600	0	0	0
North Lanarkshire	0	0	0	0	0
Falkirk	50900	182300	88000	21800	0
East Dunbartonshire	0	0	0	0	0
Renfrewshire	31200	39700	12600	0	0
Inverclyde	1500	500	0	0	0
West Dunbartonshire	1800	2800	0	0	0
Stirling	7400	5800	1400	1400	555
Clackmannanshire	700	500	200	0	0
Fife	0	0	0	0	0
Perth and Kinross	11500	300	0	0	0
Dundee City	0	0	0	0	0
Angus	300	1600	800	0	0
Aberdeenshire	300	200	0	0	0
Aberdeen City	12700	5600	0	0	0
Moray	300	200	0	0	0
Argyll and Bute	13900	11300	1300	0	0
Na h-Eileanan an Iar	0	0	0	0	0
Highland	6300	7100	1500	1700	1700
Orkney Islands	0	0	0	0	0
Shetland Islands	100	0	0	0	0
Scotland	306400	406100	149200	35500	2300

Table C-7 education (m^2 floorspace, rounded to nearest $100m^2$)

	2015-2017	2018-2022	2023-2027	2028-2032	2033-2037
Dumfries and Galloway	900	1600	1600	600	0
Scottish Borders	0	0	0	0	0
East Lothian	0	0	0	0	0
Midlothian	4600	7700	3100	0	0
City of Edinburgh	10600	2900	0	0	0
West Lothian	4500	3000	0	0	0
South Lanarkshire	0	0	0	0	0
East Ayrshire	5600	3700	0	0	0
South Ayrshire	0	0	0	0	0
North Ayrshire	900	1400	600	0	0
East Renfrewshire	0	0	0	0	0
Glasgow City	0	0	0	0	0
North Lanarkshire	0	0	0	0	0
Falkirk	0	0	0	0	0
East Dunbartonshire	0	0	0	0	0
Renfrewshire	8600	14400	5700	0	0
Inverclyde	0	0	0	0	0
West Dunbartonshire	0	0	0	0	0
Stirling	0	0	0	0	0
Clackmannanshire	500	1600	0	0	0
Fife	0	0	0	0	0
Perth and Kinross	7100	4800	0	0	0
Dundee City	0	0	0	0	0
Angus	0	0	0	0	0
Aberdeenshire	0	0	0	0	0
Aberdeen City	700	15300	14800	0	0
Moray	0	0	0	0	0
Argyll and Bute	2700	2700	300	0	0
Na h-Eileanan an Iar	1200	800	0	0	0
Highland	6300	9300	10100	5800	0
Orkney Islands	0	0	0	0	0
Shetland Islands	100	0	0	0	0
Scotland	54300	69200	36200	6400	0

Table C-8 health (m^2 floorspace, rounded to nearest $100m^2$)

	2015-2017	2018-2022	2023-2027	2028-2032	2033-2037
Dumfries and Galloway	3500	5800	5800	2300	0
Scottish Borders	0	0	0	0	0
East Lothian	0	0	0	0	0
Midlothian	0	0	0	0	0
City of Edinburgh	0	0	0	0	0
West Lothian	4500	3000	0	0	0
South Lanarkshire	0	0	0	0	0
East Ayrshire	0	0	0	0	0
South Ayrshire	34200	22800	0	0	0
North Ayrshire	2900	4800	1900	0	0
East Renfrewshire	0	0	0	0	0
Glasgow City	0	0	0	0	0
North Lanarkshire	0	0	0	0	0
Falkirk	0	0	0	0	0
East Dunbartonshire	0	0	0	0	0
Renfrewshire	0	0	0	0	0
Inverclyde	0	0	0	0	0
West Dunbartonshire	5800	400	0	0	0
Stirling	0	0	0	0	0
Clackmannanshire	0	0	0	0	0
Fife	0	0	0	0	0
Perth and Kinross	2600	1700	0	0	0
Dundee City	0	0	0	0	0
Angus	600	1000	400	0	0
Aberdeenshire	0	0	0	0	0
Aberdeen City	900	4100	3500	0	0
Moray	0	0	0	0	0
Argyll and Bute	11700	24100	6000	0	0
Na h-Eileanan an Iar	0	0	0	0	0
Highland	5600	7600	10300	11200	11349
Orkney Islands	0	0	0	0	0
Shetland Islands	0	0	0	0	0
Scotland	72300	75300	27900	13500	11300

APPENDIX D VIABILITY MODELING

D.1 Calculating site costs

D.1.1 The calculation of development costs follows the approach that has been applied in previous versions of the TELMoS model and that was originally developed for GMPTE for use with the GMSPM model[32].

D.1.2 In carrying out that project, we found plenty of analysis of the costs of building the factors affecting the costs of constructing a particular design on a given site but very little about the other elements in the overall costs of **development**. What we found was consistent with an earlier finding[33] that "It is very difficult to find past work on development costs that will inform directly the present research [into the economic consequences of alternative development patterns]"

D.1.3 In arriving at development costs for different types of location within an urban area, we therefore had to select from a wide range of detailed information about building costs, whilst being thrown back more upon our own judgement as to the other components of development cost. What we did, drawing upon the limited discussion of overall development costs in Ashworth (1999, chapter 11)[34] and Ferry et al (1999, chapter 15)[35] was to take into account five different factors, namely:

- building costs, for the building proper and for car parking;
- professional fees;
- site layout;
- costs of finance;
- demolition/land remediation.

D.1.4 Our general approach was:

- to assume (on the basis of our own judgement) a typical development of each type of floorspace in different parts of the study area;
- to extract from published cost information the appropriate building costs; and then

[32] DSC (2000): *Greater Manchester Strategy Planning Model: Revision of development costs and related work*. Report to GMPTE, November 2000.

[33] University of Reading and David Lock Associates (1993): *Alternative development patterns: Assessment.* DETR, London.

[34] Ashworth, A (1999): *Cost studies of Buildings.* Third edition. Longman, Harlow.

[35] Ferry, D J, Brandon, P S and Ferry, J D (1999): *Cost Planning of Buildings.* Seventh Edition. Blackwell Science, Oxford.

- to add what we judged to be appropriate factors for the other four elements.

D.1.5 In TELMOS14 a range of brownfield sites are modelled. The following sections describe the approach to modelling both greenfield and brownfield sites and the assumptions that will be made.

D.2 Greenfield costs

D.2.1 References to "Spon" are to Spon's Architects' and Builders' Price Book 2015 edition.

D.2.2 Costs of building are taken from Spon's section on "Building prices per square metre". The particular kinds of building referred to are documented below. Spon gives ranges of costs for every building type; unless otherwise indicated, for TELMoS14 we have taken the mid-point of the range.

D.2.3 The provision of car parking can add significantly to the costs of development, though the use of maximum rather than minimum standards has made this more variable. We have taken costs per unit of parking from the Spon section on "Building Prices per function unit" The car parking standards and types assumed are documented below.

D.2.4 Previous work had identified estimates of professional fees (architects, planning consultants, engineers, quantity surveyors) as ranging from 8% of building costs for simple developments with a lot of repetition, up to 15% for complex works with little repetition.

D.2.5 Site layout is assumed to add 4% to the costs of building works in all cases. This ratio is based on examples in Ferry et al (op cit). Likewise it is assumed that the cost of finance is 8% of the building cost.

D.3 Additional brownfield costs

D.3.1 Brownfield costs have been based upon three categories of development:

- Low Cost Site Preparation – sites with no contamination but where there will be costs associated with removal of derelict premises or previous industrial sites, colliery spoil heaps, factories where remedial work is required to address contamination and the removal of derelict premises is non-complex;
- Medium Cost Site Preparation – sites where there is likely to be some contamination or sites that were previously industrial, colliery spoil heaps or factories where the removal of derelict premises would be complex;
- High Cost Site Preparation – sites that were previously used for metal working, scrap yards, shipyards, paint and solvent manufacture, gas works, iron and steel manufacture, chemical works, refineries or ship breaking.

D.3.2 The three levels of costs were assembled from information published by English Partnerships (2008)[36]. In developing this work we've taken account of both demolition and the remediation of contaminated sites.

D.3.3 The Best Practice Note's Table 2 provides a range of costs for demolition on derelict sites, ranging (in ascending cost per hectare) from large simple sites to small complex ones. These costs include a fixed sum per site irrespective of sites; these will be converted into costs per ha assuming an average 5ha site (as assumed elsewhere in the English Partnerships note). The mid-point of each level is used to give a single cost of demolition, with a small difference depending whether the future use would be for residential or employment development.

D.3.4 The Best Practice Note's Table 1 provides a range of costs for remediation, ranging from factory sites and "works" in general (Category A) up to former gas, steel and chemical works (Category D). These costs are all per hectare, but vary by the risk to groundwater as well as by the intended future use.

D.3.5 Low Cost Site Preparation is taken to involve the more expensive of **either** demolition **or** Category A remediation – in effect this means demolition for both residential and non-residential future use.

D.3.6 Medium Cost Site Preparation is taken to involve demolition **plus** Category B remediation.

D.3.7 High Cost Site Preparation is taken to involve demolition plus the average of Category C and Category D remediation.

D.3.8 The resulting values have been converted to £/ha and inflated by RPI to make the 2007 values used in the English Partnership report consistent with the Spon values.

D.4 Typical development mixes

D.4.1 The work outlined above provides:

- greenfield development costs (building and other) for different types of housing, offices, etc.;
- costs per space for developing different types of car parking; and
- costs per hectare for site demolition and remediation, at three different levels.

D.4.2 The following are required for the calculation of the average development costs for a particular macrozone:

- the mix of types likely to be developed for each floorspace category (e.g. for housing, the mix of flats, terraced/town houses, semi-detached and detached dwellings)
- the car parking standards that will apply, and the mix of different forms of car parking that will be provided (e.g. simple ground level parking, ground level below building, semi basement), plus,

[36] English Partnerships (2008): *Contamination and Dereliction Remediation Costs.* Best Practice Note 27, revised February 2008.

- for brownfield development, the plot ratios that will apply on Low, Medium and High Cost brownfield sites, i.e. the ratio of floorspace being built per hectare of site that has to be prepared.

D.4.3 The following summarise the assumptions made in respect of each point.

Housing:

- assumed to be a mix of 25% each of terraced, semi-detached, detached and flats;
- car parking costs assumed to be included within the costs of the house;
- plot ratios assumed to be 0.2, 0.25 and 0.3 on Low, Medium and High Cost brownfield sites respectively, i.e. it is assumed that higher costs sites will be more intensively built upon.

Retail:

- assumed that the mix of floorspace to be developed is 20% small shops, 30% large shops, 10% retail warehouses and 40% supermarkets[37];
- one ground level parking space per $20m^2$ of floorspace;
- plot ratios assumed to be 0.2, 0.25 and 0.3 on Low, Medium and High Cost brownfield sites respectively.

Offices:

- assumed that the mix of office floorspace to be developed is 40% business parks, 40% other low-rise office, 15% medium-rise and 5% high-rise;
- one car parking space per $60m^2$ of floorspace, with 50% of spaces built on surface, 40% ground level below buildings and 10% semi basement,
- plot ratios assumed to be 0.3, 0.4 and 0.5 on Low, Medium and High Cost brownfield sites respectively.

Industrial:

- based on costs for developing a single basic factory form;
- ground level car parking at a rate of one space per 75 m^2
- plot ratios assumed to be 0.3, 0.4 and 0.5 on Low, Medium and High Cost brownfield sites respectively.

Warehousing:

- again based on costs for a single standard type
- ground level car parking at a rate of one space per $150m^2$
- plot ratios assumed to be 0.3, 0.4 and 0.5 on Low, Medium and High Cost brownfield sites respectively.

Hotels:

- the most appropriate costs were per m^2 of different types of hotel space: assumed 90% bedrooms and 10% reception etc.;

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[37] Note that this is the assumed mix of **floorspace**; the implication is that the mix of **units** would be quite different, with distinctly less than 40% of units being supermarkets and more than 20% being small shops, etc.

- ground level parking, at a standard of one space per bedroom (i.e. one space per 25 m^2);
- plot ratios assumed to be 0.3, 0.4 and 0.5 on Low, Medium and High Cost brownfield sites respectively.

Leisure:

- based on 50% general purposes halls and 50% "dry" leisure centres (i.e. excluding swimming pools)
- ground level car parking at a rate of one space per 50m^2;
- plot ratios assumed to be 0.3, 0.4 and 0.5 on Low, Medium and High Cost brownfield sites respectively.

D.4.4 The assumptions listed are used to calculate the capital cost of development per m^2 for each of floorspace on greenfield and on Low, Medium and High Cost brownfield sites.

D.4.5 In parallel with this enhancement we will be introducing an enhancement that permits planned development to be input as employment land – rather than as floorspace. Where this approach is applied then the employment land model will offer a choice of densities levels. In such cases the process of applying assumptions about mix of plot ratios etc. will be replaced with a number of discrete plot ratios and associated costs.

D.5 Conversion for comparison with rents

D.5.1 To measure profitability within the model, development costs need to be compared with rents. TELMoS14 requires this to be done by inputting the development costs in rent units (though in theory it could equally well be done by converting expected rents into equivalent capital values, and that would be more in line with conventional development assessments in the property sector).

D.5.2 In the present case, the development costs are

- deflated by RPI to the year in whose prices rents are measured;
- converted to annual values using an annualisation factor of 7%;
- divided by 52 to get weekly values.

APPENDIX E COEFFICIENTS

E.1 Averaging over generalised costs by mode

E.1.1 The averaging is done using the logsum formula shown at A.3.2. The mode choice coefficient is calculated using the formula shown at A.3.3 and the coefficients shown below.

Table E-1 Mode choice coefficients by purpose[i]

	Business (purpose 1)	Commute (purpose 2)	Other (purpose 3)
Λ^{M}_{REF}	-0.012	-0.0042	-0.0048
d_{ij}	900	400	2500
$-\alpha$	-0.35	-0.55	-0.4

Source: see text below

E.1.2 These coefficients were defined as a matter of judgement, informed by previous work, so as to give reasonable results for mode choice when applied to the generalised costs; a formal calibration would have been too large an undertaking, and no directly appropriate coefficients were available from previous work. However, two specific checks have since been carried out.

E.1.3 The mode choice coefficients calculated using the values from Table E-1 and the formula at A.3.3 can to some extend be compared with the mode choice coefficients used at the upper level of the mode choice model. The coefficients are fixed for all journeys, whilst ours vary by distance. For each purpose, the coefficient equals the value of our coefficient somewhere in the range 80-125Km. Broadly speaking, our model of mode choice will be more sensitive to a given difference in generalised cost at distances below that range, and less sensitive at longer distances.

E.2 Distribution coefficients: zonal accessibility by purpose

E.2.1 The distribution coefficients $-\lambda^{D}$ used in the formula at A.3.4 are fixed inputs as shown below. These are again based on judgement informed by previous projects and analysis. These calculations produce eight different measures of accessibility for each zone.

Table E-2 Distribution coefficients

Measure	Measure	Socio-economic level	Coefficient value ($-\lambda^{D}$)
1	Commuting	1	-0.027
2		2	-0.029
3		3	-0.031
4		4	-0.034

Measure	Measure	Socio-economic level	Coefficient value ($-\lambda^D$)
5	Services accessibility (consumer travel)		-0.03
6	Business-business accessibility		-0.01
7	LGV deliveries		-0.01
8	OGV deliveries		-0.01

Source: own estimation

E.3 Household incomes and expenditures

E.3.1 The coefficients of the household income function and the household expenditure function are shown in the following table.

Table E-3 Elasticities of employment with respect to accessibility[ii]

Activity	Household type	Minimum income	Additional income per worker	Minimum floorspace per household (m^2)	Proportion of discretionary income spend on housing	Proportion of discretionary income spend on other goods and services
1	YoungSEL1	90.74	553	20	0.2	0.8
2	YoungSEL2	65.14	424.8	20	0.2	0.8
3	YoungSEL3	81.87	371.03	20	0.2	0.8
4	YoungSEL4	80.18	342.25	20	0.2	0.8
5	OlderSEL1	270.42	503.3	20	0.2	0.8
6	OlderSEL2	87.89	445.4	20	0.2	0.8
7	OlderSEL3	78.61	364.45	20	0.2	0.8
8	OlderSEL4	77.97	371.81	20	0.2	0.8
9	RetiredSEL1	548.29	193	20	0.2	0.8
10	RetiredSEL2	405.18	1931.9	20	0.2	0.8
11	RetiredSEL3	349.03	1612.08	20	0.2	0.8
12	RetiredSEL4	322.02	1166.4	20	0.2	0.8

E.3.2

E.3.3 The income coefficients were derived from published analyses of ONS household and worker income data, in particular Jones (2008)[38]. The expenditure coefficients [to be completed].

E.3.4 The income components are modified each year as part of the economic scenario. The other coefficients are held constant.

[38] Jones, F (2008): The effects of taxes and benefits on household income, 2006/7. *Economic and labour market review*, vol 2 pp 37-A27

APPENDIX F ZONE AND AREA MAPS

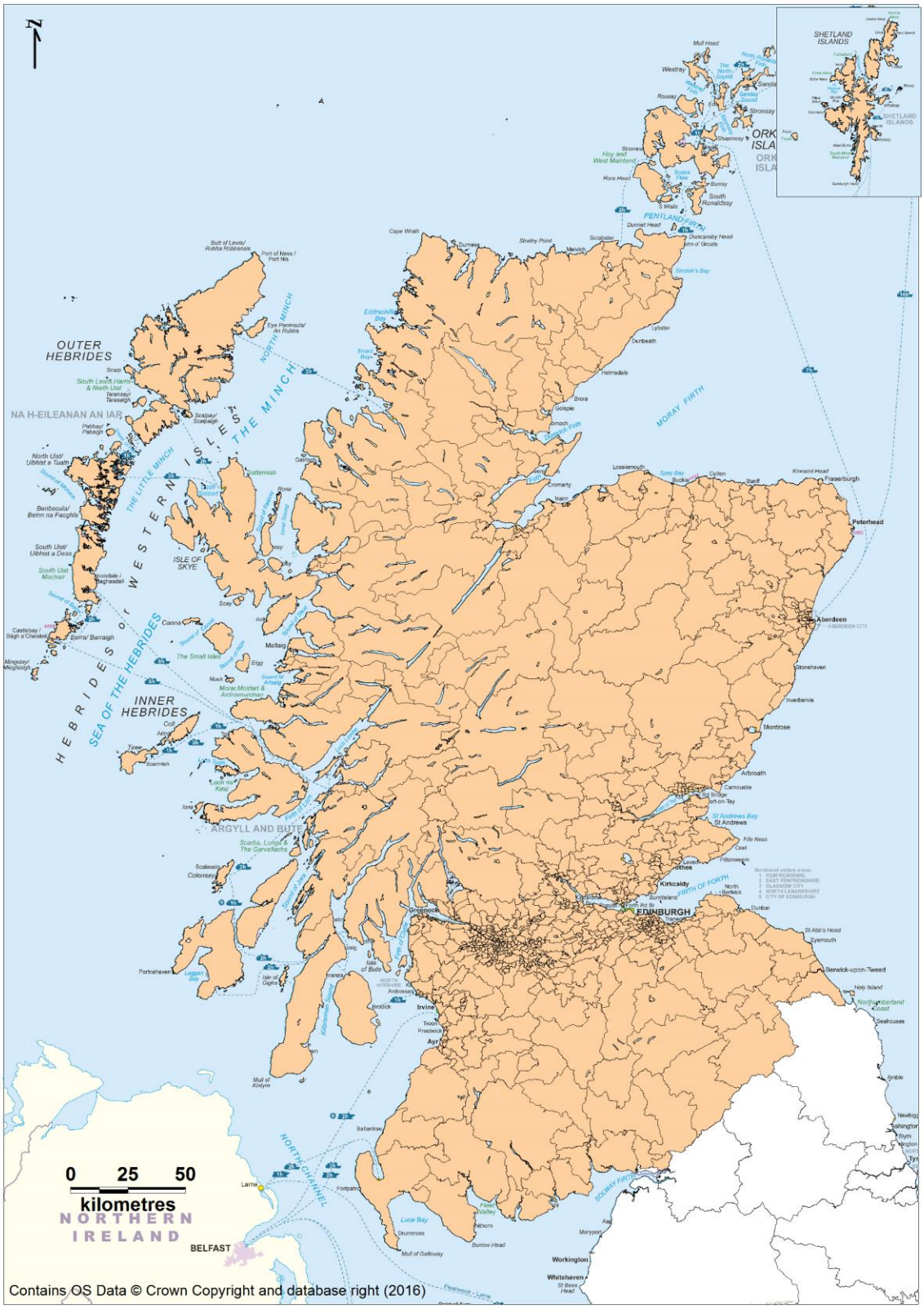

Figure F-1 TELMoS14 FMA Zone Map

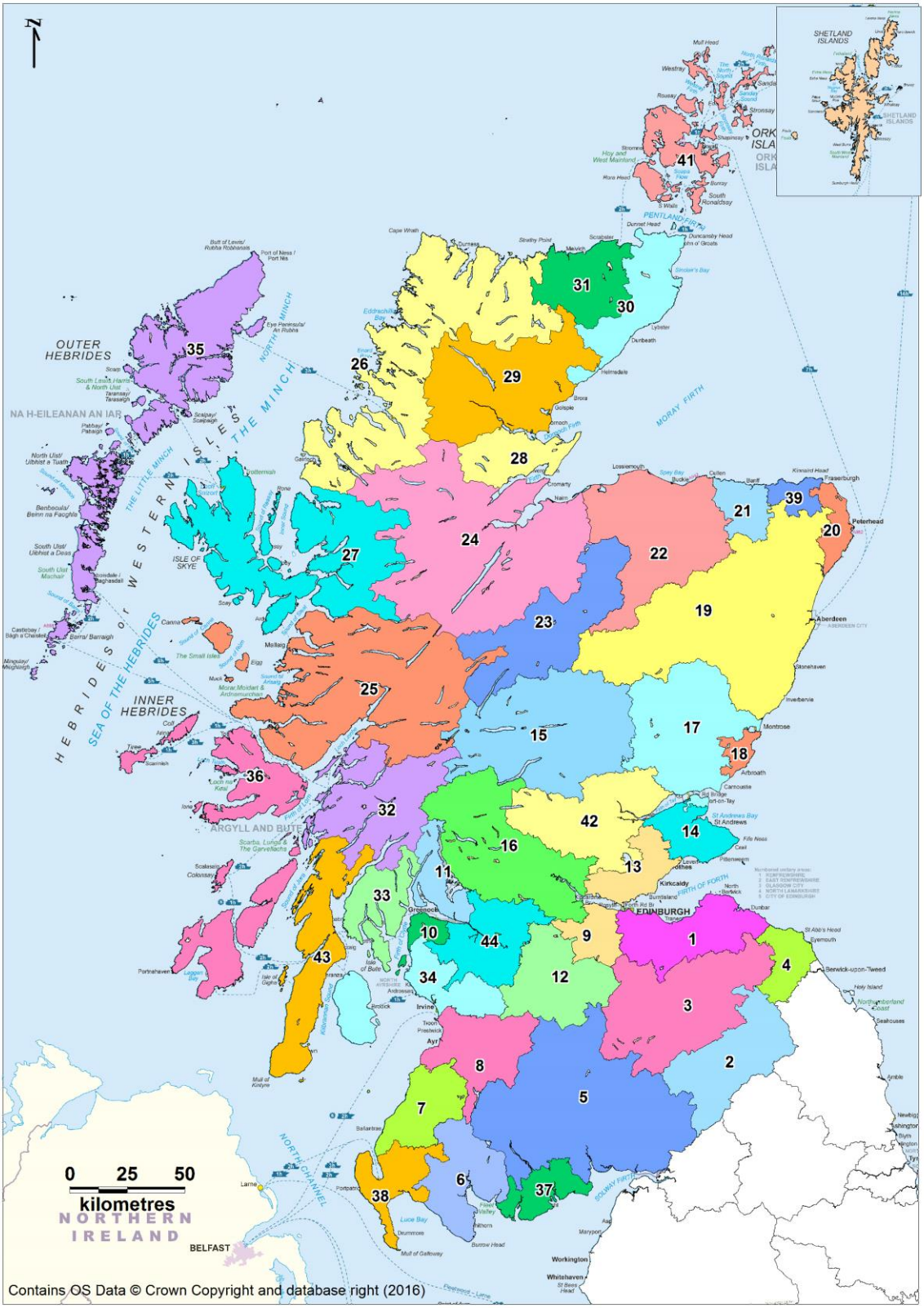

Figure F-2 TELMoS14 FMA Macrozone Map

Table F-1 Key to Macrozones

DELTA MACROZONE	DELTA MACROZONE NAME
1	Edinburgh
2	Hawick and Kelso
3	Galashiels and Peebles
4	Berwick
5	Dumfries
6	Newton-Stewart
7	Girvan
8	Ayr
9	Livingston
10	Greenock
11	Dumbarton and Helensburgh
12	Motherwell and Airdrie
13	Dunfermline and Kirkcaldy
14	St Andrews and Cupar
15	Pitlochry and Aberfeldy
16	Falkirk and Stirling
17	Dundee
18	Arbroath and Montrose
19	Aberdeen
20	Peterhead
21	Turriff and Banff
22	Elgin
23	Aviemore and Grantown-on-Spey
24	Inverness
25	Fort William
26	Ullapool
27	Broadford and Kyle of Lochalsh
28	Alness and Invergordon
29	Golspie and Brora

DELTA MACROZONE	DELTA MACROZONE NAME
30	Wick
31	Thurso
32	Oban
33	Dunoon and Rothesay
34	Kilmarnock and Irvine
35	Eilean Siar
36	Portree
37	Dalbeattie and Castle Douglas
38	Stranraer
39	Fraserburgh
40	Shetland Islands
41	Orkney Islands
42	Perth
43	Campbel town
44	Glasgow

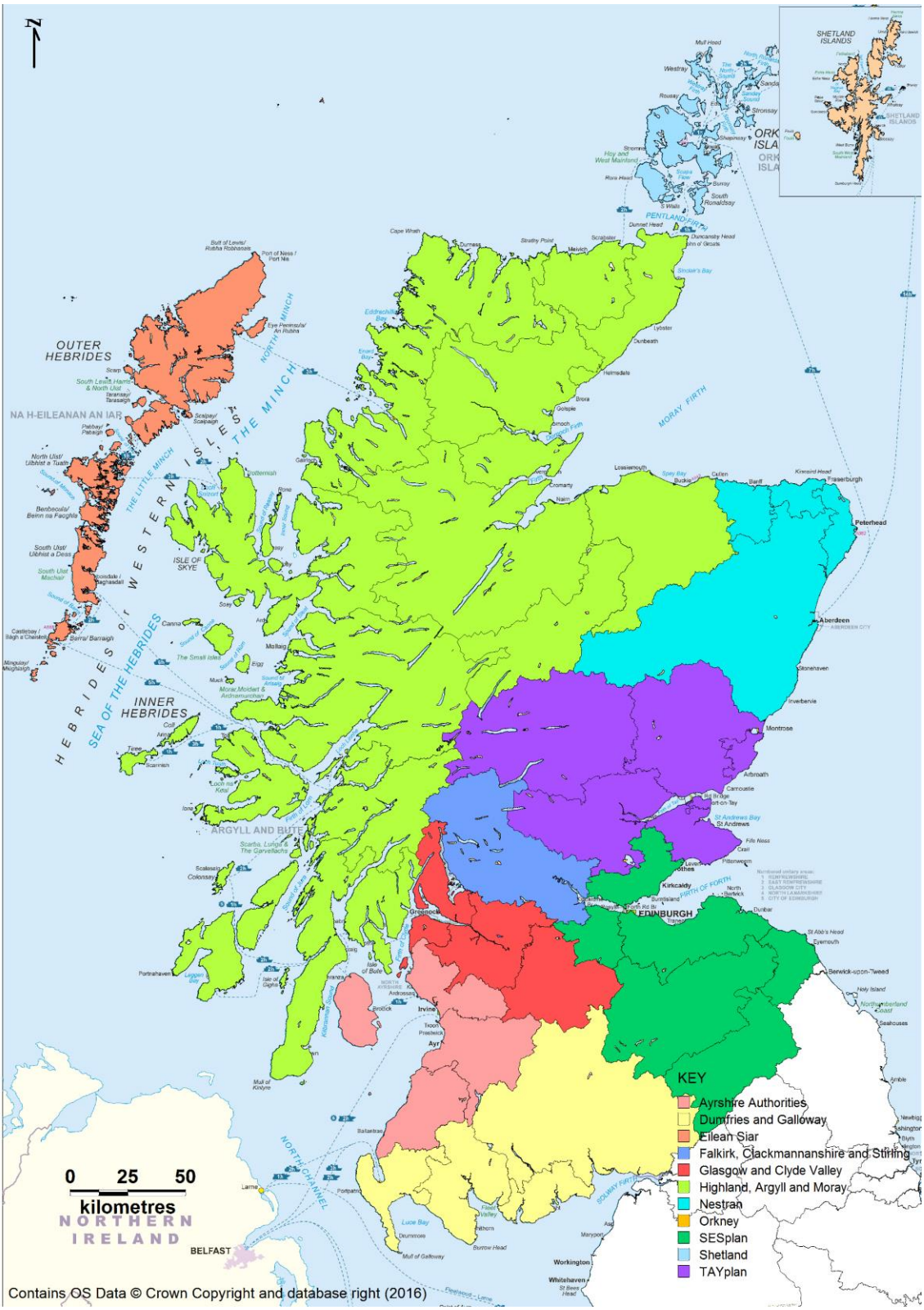

Figure F-3 TELMoS14 Regions as defined in Table 6-1