

**Transport Scotland  
Audit of the Transport/Economic/Land-Use Model of Scotland (TELMoS)  
Phase 1 Audit Note AN8-2**

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**1 INTRODUCTION**

**1.1 Overview**

This note outlines the main findings within the Phase 1 of the audit of the Transport/Economic/Land-Use Model of Scotland (TELMoS). This audit is part of TMfS Audit Task 8 (Review of TELMoS)

TELMoS has been an integral part of the forecasting process for the Transport Model for Scotland version 02 (TMfS:02). It has been retained for the latest version of TMfS:05, and it is planned that TELMoS will be further enhanced for TMfS:07.

Due to its scale and complexity, the audit of TELMoS has run with a different timescale from that of the general TMfS:05 model development audit work.

**1.2 TELMoS Audit Tasks & Timescales**

The main tasks associated with the audit of TELMoS are based around a review of the following:

- General form and specification of model
  - Empirical underpinnings of model mechanisms
  - Calibration strategy
  - General model validation
  - Sensitivity testing
- } Phase 1

} Phase 2

The audit is being undertaken with short and medium term deadlines, indicated respectively above as Phase 1 and 2. In the first instance, we (the TTAA) seek to provide findings regarding the form and specification of the model, the model mechanisms and the calibration strategy in the short term. Additionally, materials related to general model validation, and an examination of the outcomes from on the shelf sensitivity tests are reviewed in Phase 1 to establish an initial view of the realism and robustness of the model responses. It is anticipated that the Phase 1 audit findings will be presented at the beginning of October 2007.



The medium term audit findings will seek to examine further the model validation and the response across a wider range of tests. In some cases, it would seem necessary to commission additional sensitivity tests or await the outcomes from on-going studies to provide the necessary information to enable the audit to be undertaken. We propose that the medium term audit work will begin in earnest following the publication of the Phase 1 findings. **It will be necessary for us as TTAA to consult with Transport Scotland, MVA and DSC to identify resources and establish a programme for the continuing audit work including undertaking sensitivity tests and examination of output from on-going studies.**

### 1.3 TELMoS Phase 1 Audit output

To facilitate the understanding of the complex land use modelling issues we have developed a two level documentation for the TELMoS Phase 1 audit:

- first, a short note (i.e. this one) that summarises the main issues with minimal technical jargon so that it can be understood by interested but non-specialist readers
- secondly, we have requested the production of a set of technical 'Project Notes' by David Simmonds Consultancy (DSC); we have reviewed and commented on the drafts of these notes and they are now complete in their final form. These Project Notes provide further technical details on the discussions covered by this note.

### 1.4 List of working documents

The audit is based on a wide range of information provided by:

- David Simmonds Consultancy (DSC), the developer of TELMoS
- MVA, the lead consultant for TMfS

The initial information was a TELMoS **Model Description** report (DSC, Feb 2007), which was supplied by DSC for the purposes of the audit. This report was itself derived from a report originally drafted in 2005. The earlier material was however intended to be read in conjunction with the DELTA Manual, and as such was not a free-standing document. The current version of the Model Description Report was the first free-standing documentation of TELMoS, covering, at varying levels of detail, the following aspects of the model:

- Basic model definitions
- Urban database definitions
- Database development for Base Year, 2001
- Processing of other information for 2001
- Regional economic model database
- Urban models and their input files
- Regional model input files
- A brief outline of the TELMoS/TMfS interface
- A brief outline of scenario inputs

During the Phase 1 audit, a number of supplementary documents have been produced upon our request to clarify queries or deal with topics that have been omitted in the Model Description Report. These are:

- DSC Project Note 23 'Economic and transport cost scenarios', which outlines the results from 8 existing scenarios that have been tested as part of a TELMoS project during 2006

- DSC Project Note 32 'TELMoS population projections', which compares the current TELMoS population projections for Scotland as a whole with those published by GRO(S) and in TEMPRO
- DSC Project Note 33 'Controlling TELMoS Forecasts', outlining how TELMoS is or can be controlled to match external forecasts at different levels, from Scotland totals down to individual zones
- DSC Project Note 35 'TELMoS/TMfS linkages', including a full list of the data exchange between TELMoS and TMfS
- DSC Project Note 36 'TELMoS Model Calibration', which clarifies the data used in model estimation, and comments briefly on the possibilities of collecting new data for formal calibration of economic and employment models within TELMoS
- DSC Project Note 42 'TELMoS: Proposals for updating the planning policy inputs', which describes the general approach to gathering policy data previously, issues that arose from that exercise, the process and timetable for revision to the planning policy inputs, and an outline of the information DSC will request from the local authorities
- a note summarising the experience on working with local planners and considerations for future planning data collection
- an outline presentation of the TMfS/TELMoS West Edinburgh planning and transport scenario tests, which the Scottish Executive as client for that project have granted permission for access by TTAA
- DSC note on 'preferred Census tables' contributing towards the 2011 Census consultation, which is an important consideration for land use data sources in the longer term

In relation to travel demand modelling, MVA has provided the TMfS Demand Model Development – 2005 Rebase Draft Report (MVA, November 2006).

All the information above has been very helpful for the Audit, and we wish to thank Transport Scotland, the Scottish Government, DSC and MVA for their full support throughout the Phase 1 work.

## 1.5 Contents of this audit note

The rest of this note consists of:

- the main findings, in Section 2
- summary and the main recommendations, in Section 3



## 2 MAIN FINDINGS FROM PHASE 1 AUDIT

### 2.1 Overview

It has been agreed in discussion with DSC that the audit should be divided into two main areas: i) model development and ii) model applications.

**Model development** - the main aspects that have been discussed under this heading are:

- Model documentation
- Empirical underpinnings of the model mechanisms
- Calibration strategy
- Model validation
- TELMoS-TMfS data interface
- Maintaining a consistent audit trail for the use of empirical data

**Model application** - the main aspects are:

- land use planning data collection
- existing model runs as sensitivity tests for the audit

The interest in existing model runs in this context lies in possible efficiency savings in the auditing process. Given that DSC already have a heavy workload in the on-going model tests for Transport Scotland and would have very limited resources for new sensitivity tests, it would be preferable to use existing material for examining sensitivities in the current phase of the audit.

The main findings obtained from Phase 1 are reported below. As is usual with any auditing exercise, the focus of the reporting tends to be concentrated on areas that are either weak or uncertain, such that constructive recommendations can be put forward for future improvements. One should bear this point in mind when reading the findings below, lest the comments may appear to be somewhat negative.

### 2.2 Description of the TELMoS Model

The TELMoS Model Description Report (DSC, Feb 2007) is the first freestanding document that systematically describes the model, and it is much welcomed by us as the TTAA. It provides useful details of the implementation of the land-use and economic components of TELMoS, and their interactions with the transport components of TMfS. It provides a clear description of the model definitions, the processing of the 2001 Census data, other data sources for setting up the Base Year model for 2001, the regional economic database, the structure and inputs of the urban and regional models, the DELTA/TMfS interface, and a brief outline of the scenario inputs.

Broadly speaking, it is clear from the TELMoS Model Description Report that the model structure of TELMoS is well designed, with sensible definition and segmentation of land use and economic activities, and linkages between those activities. We consider that the model design and structure are in the main consistent with good practice of land use activity and travel demand modelling.



The TELMoS Model Description Report provides a good foundation for further examination of the model, particularly in terms of empirical underpinnings of the model mechanisms, calibration strategy, sensitivity testing, and model validation.

As a first version of this Model Description report, the levels of detail on different aspects of the model are uneven. Some key areas of the Report can now be improved through incorporating appropriate sections from the Project Notes and supplementary materials listed above, which have been produced by DSC during the Phase 1 audit.

We have also made a list of reviewing comments on the TELMoS Model Description Report. DSC has addressed the majority of the comments. For some technically complex questions, DSC agree that further checking/clarification is desirable, though it would not be possible to take them further in the time available within Phase 1. These remaining areas have been considered below in the findings and recommendations.

### 2.3 Empirical underpinnings of the model mechanisms

In a broad sense, the empirical underpinnings of the model would include:

- the data sources that have been used in estimating the model
- the ways in which model parameter estimation has been carried out (i.e. model calibration)
- the ways in which the model results are compared with real and appropriate data so as to ascertain the validity of the model (i.e. model validation)

Obviously these are important areas for the audit of a simulation model like TELMoS. Strong empirical underpinnings to the model provide the foundation for evidence-based policy analysis.

The current version of the Model Description Report only provides information on model estimation methods and data sources in a very limited number of areas. Upon our suggestion, DSC has produced Project Note 36, which is a comprehensive note on calibration, covering some 40 different model mechanisms used with TELMoS<sup>1</sup>. In this note, the ways in which model parameters and coefficients have been established in TELMoS are reviewed. Four distinct ways have been identified, i.e. the model parameters and coefficients are:

- i) taken directly from published statistics
- ii) formally estimated by statistical or other methods
- iii) derived so as to reproduce estimated elasticities, average distances or comparable measures obtained in other research or reported in the literature
- iv) based on judgement (informed by e.g. previous modelling experience in other study areas)

The majority of key model parameters and coefficients in TELMoS have been obtained through iii) and iv). In the case of iii), significant adjustments or conversions had to be made to the original data sources. In most such cases, parameters and coefficients based on iii) are also to a large extent based on iv). In a significant number of cases the audit trail for the use of empirical data is not yet clear.

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<sup>1</sup> These model mechanisms are components of the TELMoS model (such as those representing household transition amongst the life cycles, or floorspace development. They are sometimes called 'sub-models', or even 'models' for short.



This raises real concerns with the strength of the empirical underpinnings of the current TELMoS model:

- DSC has already identified a number of areas for the model enhancement programme, which with appropriate scoping could improve the empirical basis of the model. We agree that those are important areas to improve, although our concerns would often go beyond the current DSC proposals in terms of empirical underpinnings.
- In our review, we have also identified a number of other areas where the robustness of the model mechanisms should be examined through formal sensitivity tests.

We comment below on those areas where we have significant concerns. Note that these are based on the review of existing documentation only and they are not meant to form an exhaustive list. Also the order of the items below does not necessarily imply the order of priority.

### ***Areas associated with the DSC's model enhancement proposals***

DSC has identified the following areas where the calibration of the model could be improved through the proposed enhancement work. This in some cases involves improvements to model design as well as calibration. The text below has incorporated DSC's recent feedback to us.

**Enhancement E04b - Household location model:** this would update the household location model within TELMoS with the latest, improved DELTA household location model. This would model household relocation explicitly, as zone to zone matrices of household movements, whereas in the existing TELMoS only the net movements from and to each zone are explicit. DSC believes that this enhancement would allow the model calibration to make better use of 2001 Census data on patterns of household relocation and to draw on new reported material from other studies.

Directly linked to this task, DSC has recommended a household location/relocation survey (mentioned in the Enhancement Report under the heading “national/regional economic and geo-demographic assumptions”). This would allow the calibration of the household modelling to be supported by analysis of data from a bespoke survey of household location/relocation choices, including Stated Preference questions to overcome the familiar problem of correlation between the independent variables (e.g. correlation between accessibility and price). It would in particular seek to improve the understanding of how transport and accessibility affect household location decisions. This would substantially increase the proportion of the main model coefficients that are based on formal estimation (i.e. Approach ii) under paragraph 2.3).

The proposed improvements to household location modelling could bring the TELMoS model up to the standard of best practice as represented in other DELTA models by drawing upon the improvements which have been made in other projects.

However, the observed data on household movements is currently patchy. Also, the scale and complexity of the household survey that would be required to guarantee a rigorous calibration would be demanding in terms of cost and skills required. **We recommend that the way in which the observed data is used to build the model should be scoped carefully to ensure a satisfactory outcome.**

**Enhancement E04c - Modelling journeys to work:** At present, a synthetic journey to work matrix segmented in two socio-economic groups and 3 car ownership levels is generated within TELMoS, which has not been compared with observed journey to work matrices (such as in Census 2001). This is because when TELMoS was implemented, the Census 2001 journey to work data was not yet available. DSC has proposed within this task to rebuild the travel-to-work patterns using the 2001 Census data, which will then replace the present synthetic matrix. This would improve the calibration by using observed data directly (though an element of

modelling will still be needed to obtain the required matrices by socio-economic level and car-ownership/car-availability). The enhanced modelling of travel-to-work would then form an incremental model based upon the 2001 data, which has already been the standard practice in models developed under other software packages.

**We note that, in effect there are two separate commuter travel models - one in TELMoS and the other in TMfS. It would be important to compare the implied commuter travel demand responses of TELMoS, against those of TMfS (cf. MVA, November 2006).**

It is noted that the commuting models of TELMoS and TMfS undertake different roles (the TELMoS model is concerned with average journey to work patterns by mode over the course of a day, whilst TMfS is concerned with commuter matrices by car and PT within different time periods of a day). However, the implied elasticities still need to be consistent once these differences are accounted for. This is to ensure that there are no major differences in the implied commuter travel demand elasticities. The parameters concerned include the TELMoS mode split coefficients and constants and the distribution coefficients that are used in the DELTA accessibility calculations. The current version of TELMoS Model Description has not reported all the key parameter values.

DSC have agreed to consider this issue and particularly to ascertain if any revision of the TELMoS parameters would be required as part of the enhancement.

**Enhancement E04d - regional economic and employment location modelling**, which DSC believes should at least include:

- to adjust for the changes to the generalised cost inputs to these components which will arise from changes to TMfS
- to update the model further using information on observed changes since 2001

This would include the opportunity for further testing and adjustment of the economic/employment responses in the model. In preparing the enhancement proposals report DSC did not originally propose to collect new data for more formal calibration of these responses. However, during the Phase 1 audit more thought has been given to this aspect upon our request, as regional economic and employment modelling would be within the very core of TELMoS. DSC have not had time yet to consider this in detail, but they would be inclined to explore a possible survey of key decision-makers in a sample of organizations<sup>2</sup> of different sizes across different sectors. The survey would ask about the factors affecting the location of business establishments. DSC would see this as differing from the generality of such surveys in terms of:

- using Stated Preference techniques to ask about the response to hypothetical changes as well as asking about the rating of different factors
- avoiding general terms such as “accessibility”, but asking specifically about the role of transport such as the ability to serve markets, the ability to recruit appropriate labour, the ability to interact with other firms or establishments, etc
- looking at decisions to increase or decrease investment in existing establishments as well as at decisions to locate or relocate whole units

Like various other studies, the survey would recognize the distinction between different levels of spatial choice, e.g. between regions of Scotland, or between specific locations within a region. It would expect to find different factors being prominent at different levels. Overall the survey work would aim to facilitate:

<sup>2</sup> Mainly private sector businesses, but possibly also some public sector organizations.

- confirmation or adjustment of the sets of factors influencing the location of investment (upper spatial level) and of employment (lower spatial level) in TELMoS
- confirmation or adjustment of the specific measures used for complex variables such as market size
- adjustment of the weights on the variables in the various choice processes

DSC proposes that this be complemented by additional fieldwork amongst commercial property specialists (see below), to enhance the modelling of the ways in which changing business demand (and changes in the factors affecting such demand) affects commercial property markets. This would in effect draw in evidence on the aggregate effects of changes in factors affecting commercial property users, to supplement the business survey which would be looking at the effects of such changes in individual businesses.

We note that, given the heterogeneity of firms, a rather large sample would be required to ensure a solid empirical base. This task is likely to require significant resources. **We recommend a careful scoping be carried out to ensure a satisfactory outcome.**

**Enhancement E04f - Floorspace development model:** DSC propose to recalibrate the development model, along with improvements in model design. This would provide the opportunity for further adjustment of the development responses, and possibly with more formal calibration if appropriate data could be identified. If the model design improvements are adopted then further judgement inputs to model calibration would be sought from the expert panel.

TTAA welcome this initiative. According to the current version of TELMoS Model Description, the floorspace development model is based on assumed elasticity values which are in turn derived from limited and unpublished sources. **DSC's proposed enhancements would strengthen the empirical basis of this part of the model, on the assumption that satisfactory data sources could be identified to provide good quality model calibration.**

***Significant issues that have not been included in current enhancement proposals***

**We have also identified a number of other modelling areas that should be further examined in terms of the robustness of empirical evidence and model estimation.** These are issues that do not appear to be considered yet in the current enhancement proposals, but they should also be considered when drawing up the priority list for future enhancements.

**Use of the Scottish Input-Output Table.** The Scottish Input-Output Table is a key input in TELMoS regional economic modelling. The input-output coefficients represent the technology of production, preferences of consumption of the final consumers, and the structures of external trade and investment at a given point in time. The values of these coefficients within TELMoS were derived from Scottish Economic Statistics 2003. However, it appears that these coefficients are not updated through time to take account of changes in production technology, consumption preferences, and structures of trade/investment. This omission may explain some of the queries arising from the sensitivity tests on alternative GDP growth scenarios (see below under existing sensitivity tests). **DSC would need to clarify the implications of using fixed input-output coefficients through time.**

**Car-ownership model.** It would appear that the car ownership model within TELMoS does not respond to changes in residential car parking restrictions. The inclusion of residential car parking restrictions has been suggested in the past, but that suggestion was rejected owing to the difficulty of obtaining sufficient information about the scope for off-street car-parking. DSC recognise that the availability of car parking is an influence on car-ownership (and on residential location) and would like to incorporate this if suitable data sources become available. **This omission may become a major issue if/when testing urban densification schemes where**

**residential car parking is not expected to increase in line with the construction of dwellings.**

**Use of Census and other demographic data.** Demographic data sources, particularly Census 2001, are extensively used to support TELMoS. This makes it important to examine whether such demographic data has been used appropriately in modelling. The following issues have been identified during our review:

- **Census under-enumeration and comparison with mid year estimates.** As noted in DSC Project Note 32, TELMoS has made direct use of the Census data without adjusting for under-enumeration or to match the 2001 Mid Year Estimates. This would under-estimate total population in some areas (although such local effects may not be obvious in the total population figures). **Given that official future year population projections are based on Mid Year Estimates which correct for Census under-enumeration, it would be preferable for TELMoS to use the Mid Year Estimates as definitive population figures in any future revision of the TELMoS base data.**
- **Assumptions regarding advanced segmentation of households and population.** The TELMoS demographic models require sophisticated segmentation of households and population, e.g. in its household transition modelling, and in the modelling of labour demand by industries. DSC has made use of the Scottish Household Survey (SHS) data in addition to the Census for this. However, the SHS and Census data are often not available at the level of the detail required. We recognise that it is permissible for modellers to make assumptions in order to split the available data into more detailed categories in model implementation, if this leads to improved modelling of behaviour. However, we also note that such assumptions within TELMoS are often not explained in terms of their empirical robustness. For example, in life-cycle modelling of the population, the different income groups are not differentiated; it is not clear how the manual/non-manual split have been assumed by industry or employment activity; also, where the SHS and Census both provide information on a data item, it was not clear how the two sources were combined when deriving model inputs. **DSC to clarify a number of queries on this in the Model Description Report.**

## 2.4 Calibration strategy

We recognise that the current weakness in empirical underpinning mainly stems from the lack of appropriate data, which in turn could have been the result of the lack of resources in data collection or model development in the past. However, we also note that the DELTA model calibration strategy may have contributed in some instances.

In the current version of the TELMoS Model Description, DSC commented that (DSC, Feb 2007, p35 paragraph 7.1.4) 'it has never been the intention that DELTA models should be extensively calibrated in each of the areas to which they are applied. The philosophy behind the model is that the coefficients should be chosen so that the model reflects the accumulated understanding obtained from past research and analysis. This may mean that particular coefficients (or ratios of coefficients) can be taken directly from previous work; more often, it means that the coefficients must be adjusted so that the model reproduces particular effects (such as elasticities) which are expected on the basis of previous work. In practice, many of the coefficients were chosen and tested in earlier DELTA applications and have been reapplied, with limited testing of their individual effects'.

We welcome the DELTA approach to accumulating the understanding from past successive modelling projects. This helps to build up the evidence base and benchmark for empirical performance of the models in the field of land use modelling.

However, it is not clear to what extent and in what circumstances the model parameters can be transferred without carrying out appropriate testing of their effects. **We consider it important to justify the model parameters specifically for TELMoS, rather than simply re-using parameters from other DELTA-based studies. This could be done as part of a carefully designed set of model sensitivity and validation tests on model performance, and should not involve significant extra resources.**

## 2.5 Model validation

To date there have been few efforts to validate the TELMoS model. 'Validation' here is in the sense that the model results are compared with real data so as to ascertain its empirical validity. In the past, this could have been because of the lack of observed data. Also, for some model mechanisms such as the household transition model, tests between Census years (such as 1991 and 2001) would be necessary and presumably no resources were available to set up and run the model from 1991 to 2001 to assess its performance between two Census years.

One related exercise carried out during the Phase 1 audit was the comparison between the current TELMoS population projections for Scotland as a whole with the official population projections published by GRO(S) and a further dataset in UK DfT's TEMPRO database. This is presented in DSC Project Note 32 'TELMoS population projections'. This exercise compares different growth trends into the future.

Strictly speaking, this comparison is not model validation, as the TELMoS outputs are compared with other projections rather than observed data. However, the comparison would give an insight into the forecasting performance of TELMoS.

Since the GROS projection is the official projection in Scotland, the comparison between TELMoS population forecast and the GROS projections is the more relevant. The comparison shows that:

- the two datasets have almost the same national totals in 2001
- the TELMoS total falls for the first three years, recovers slightly, and then shows a very slight, continuing decline to 2021. The decrease in the first year is in the same direction as the GROS projections, but too rapid. From then on the GROS projection shows a marked increase in population. The TELMoS total population in 2021 is some 120,000 less than in the GROS projections owing to the different trajectories of growth/decline.
- this declining profile within TELMoS is the result of the workings of the household transition sub-model within TELMoS, which forecasts households changing from one type to another (eg from couple to couple-with-children), together with the input average household composition for each household type (e.g. the average number of children in each couple-with-children).

Although the population total comparison described above is not a strict validation exercise, it highlights the importance of comparing model outputs with observed data and external projections when attempting to understand the model results.

DSC suggests that the modelling of population totals may be adjusted in the current STPR work, if time and resources allow, and it would in any case be revised in the proposed enhancement project. The DSC Project Note 33 was produced to present the possibilities of controlling population and household totals within TELMoS.

**We welcome this proposal. There is often a need for land use modelling to conform to the official demographic (e.g. population and household) and economic (e.g. GDP) projections for the whole study area. We recommend that in future the clients of TELMoS should**

**provide explicit guidance to TELMoS regarding whether there are any official demographic or economic projections at the whole study area wide level that TELMoS should conform to.**

The DSC Project Note 33 also highlights that external controls of total households, population or employment at the study area wide level, albeit feasible, could in some cases adversely affect the model results in some local areas. This raises the question of compatibility between the assumptions made in TELMoS with those made in the external projections. For instance, it could be harmful to the model forecasting results, if the TELMoS model input assumptions would lead to a declining total population, whilst the population control total would force the model to produce a significant growth in total population. In other words, it would necessary to ascertain that the control totals to be applied are compatible with the employment or demographic processes within the model (e.g. no significant growths such as in-migrants were missed in the model). **This suggests that it would be necessary for DSC to verify the impacts of imposing external control totals (either nationally or locally) and report them as necessary.**

**We will suggest a number of possible tests be included in standard model validation, under Phase 1 Audit Recommendations below.**

## 2.6 Interface with TMfS

DSC Project Note 35 ‘TELMoS/TMfS linkages’ includes a full list of the data exchange between TELMoS and TMfS. This has greatly supplemented the information presented in TELMoS Model Description, and we expect the information in Project Note 35 will find its way into a revised TELMoS Model Description.

During the review we identified two issues with the TELMoS-TMfS interface, as discussed below.

**First, the potential for enhanced interface. There appear to be a much greater potential for passing model data between the two models than currently implemented. This would enhance the modelling of land use/transport interaction, and thus in the longer term gradually catching up with best practice of land use/transport interface in this field of modelling. For example:**

- TELMoS simulates household and commuting using excellent socio-economic categories, which could support much improved modelling of trip generation, distribution and possibly mode choice in TMfS. However, these socio-economic categories are currently aggregated into one before sending the information to TMfS.
- Also, the monetary transport costs (i.e. car operating costs and PT fares) and times of travel estimated in TMfS are aggregated into one generalised cost measure before being sent to TELMoS, which implies that in TELMoS:

i) the estimation of the households' cost of living does not take into account of the travel costs as measured on the transport networks in TMfS

ii) there is a loss of flexibility in calculating transport accessibilities

**Secondly, land use/transport interaction.** It is not clear whether the generalised transport costs from TMfS and the land use data from TELMoS are strictly compatible for a given year.

For example, if TMfS is run for 2006, 2011 and 2016:



- TELMoS will use the 2006 TMfS car and PT costs to produce a forecast of land use activities for 2007 to 2011 inclusive. The land use model will be run for every year, but all years 2007-2011 will use the 2006 transport costs without accounting for the possible build-up of congestion in the period or for improvements resulting from transport schemes
- At Modelling Year 2011, TELMoS will send land use data (forecast on 2006 travel costs) to TMfS; this set of land use data will not have accounted for any transport changes 2007-2011
- TMfS will use this land use data (which reflects no transport changes 2007-11) in its travel demand estimation for 2011, and feed the transport costs back to TELMoS for producing land use results of 2016

TELMoS does not appear to have attempted to interpolate generalised costs (and hence the effects of congestion etc) between the years in the transport model is run. DSC suggests that this is not a simple problem, because interpolation will only be appropriate for gradual changes, not for step changes arising from new infrastructure or charging. This can obviously result in some shocks to the land-use model when it suddenly 'discovers' the effects of say 5 years' growth in congestion. DSC's preferred solution to this is to run the transport model more often, but that is not practical in the TMfS case.

As it stands, the TELMoS interface with TMfS would not appear to be the best practice in land use/transport interaction modelling. DSC consider that in the context of DELTA applications the best practice in the UK is represented by the SITLUM and SETLUM models, each of which runs the transport model every alternate year. This provides a far better exchange of data between the land use and transport models, although naturally, the more frequent the interface, the more transport model runs will be required, thus requiring longer overall model run times for a given forecast horizon.

It is also useful to highlight an alternative approach to land use/transport interface. In version 3.0 of the London and South East Model (LASER)<sup>3</sup>, the interface between the land use model and transport model enables the two models to run through 3 cycles for each modelled year, i.e.

- The land use model is fed with up-to-date transport information which takes account of transport schemes and cost/fare changes
- The transport model then uses the land use results generated above for travel demand and congestion modelling
- The above process is repeated 3 times for each interface year, such that the land use and transport results reach a stable and consistent solution (i.e. through iteration).
- Nevertheless, in version 3.0 of the model, this iterative interface occurs only for two future years: 2016 and 2031
- One may argue that over a 15 year period, the number of times a land use model interacts with a transport model in LASER3.0 is the same as in TELMoS. However, without appropriate simultaneous iterations between land use and transport within a given interaction year (e.g. 2001, 2006, etc) the land use and transport model results may not be stable enough to inform policy analysis.

It is not currently clear the extent of this lack of simultaneous iteration between TELMoS and TMfS within a given interaction year (e.g. 2001, 2006, etc) affects the land use results in TELMoS and the transport results in TMfS<sup>4</sup>. **It would be appropriate to carry out a**

<sup>3</sup> Which is based on the MEPLAN software, rather than DELTA.

<sup>4</sup> This is a separate issue from the one of whether households/businesses anticipate network changes (e.g. new highways or bridges) in making location/development decisions.



**sensitivity test to ascertain if any adverse effects could result from this incompatibility, and to modify the interface design if proved necessary.**

## **2.7 Audit trail regarding the use of empirical data in model development**

At present it would appear that the audit trail regarding the use of empirical data in model development has not been fully maintained. In some instances, some searching in archived tests are still required to retrieve the model runs where the coefficients were adjusted, and there are still substantial difficulties in tracing back the derivation of some of the key model parameters and coefficients such as those used for key calculations of transport accessibilities.

The production of the first edition of the TELMoS Model Description Report has provided a useful foundation for building up the audit trail, and **we very much hope that the momentum of model documentation is maintained and a complete version of the Model Description Report is produced soon.**

## **2.8 Land use planning data collection**

During the Phase 1 Audit, DSC produced two notes on land use planning scenarios:

- DSC Project Note 42 'TELMoS: Proposals for updating the planning policy inputs', which describes the general approach to gathering policy data previously, issues that arose from that exercise, the process and timetable for revision to the planning policy inputs, and an outline of the information DSC will request from the local authorities
- A further note summarising the experience on working with local planners and considerations for future planning data collection

DSC has highlighted a number of points which have been learnt from previous interaction with local planning authorities, not just in relation to TELMoS:

- There is a need to try to ensure that the model inputs requested from LAs are as close as practically possible to the concepts and units that the local authorities routinely work with (e.g. industrial land rather than industrial floorspace).
- Likewise there is a need to allow for most LAs to be reactive rather than proactive in relation to some key aspects of development (e.g. much of retail development); as a result they do not necessarily consider the total quantity of development (and redevelopment) that may occur, or at least they do not attempt to identify where this will occur, in the same way that they have to do for housing. Either the preparation of the planning policy inputs to the model, or the treatment of planning policy in the model itself, needs to allow for the likelihood that in such situations the rate of development activity will be substantially greater than the current LA view on "expected development".
- There is difficulty in getting some of the LAs to agree to specific set of inputs beyond the horizons of their formally approved plans.
- There are significant differences in approach to assessing expected/foreseeable development (eg as a result of different treatments of windfall sites, or whether gross development is distinguished from net) which pose problems in ensuring that the modelled representation of planning policy is consistent between local authority areas.

The first three of these are expected to be addressed through the floorspace development model enhancements proposed for TELMoS:07. The last one, DSC feel, can only be dealt with through working closely together with LAs during the preparation of the planning policy information for modelling.

We are pleased to see that DSC has established sound principles for future land use planning data collection, which is in line with the principles adopted elsewhere. However, their note also highlights the very substantial difficulties in actually obtaining the data required for the empirical estimation of the floorspace development model. The empirical robustness of the model would be dependent on a successful collection of all the data required by the model specification.

## 2.9 Existing model runs as sensitivity tests

During the Phase 1 Audit, DSC has supplied:

- Project Note 23, which presents the run results for 8 land use and economic scenarios)
- An outline presentation of a West Edinburgh planning scenario test

We have reviewed these, with a view to identify potential material that could be used as off-the-shelf sensitivity tests.

**The 8 land use and economic scenarios.** These tests provide some useful insights into the working of the model. However, the results presented in the note are not sufficient to clarify those issues raised earlier in this Audit Note. In addition, a number of queries were raised on some of the results, i.e:

- large finance sector changes in Edinburgh in JV and JX runs vs JW, which appear to be out of line in comparison with other areas
- very small responses in household location after 10 years of significant travel cost increases
- clarify the growth rates in Table 3-1 of Project Note 23
- the reasons behind the rapid rise of primary and manufacturing sector employment under the high economic growth scenario, which does not appear to be in line with the current understanding of new growth sectors in the economy

DSC is investigating these queries at the time of writing this note.

**West Edinburgh planning scenario test.** The land use model results included in the outline presentation of this test were very limited, given that the main focus of the test was with the travel demand and traffic models. MVA, the lead consultant for TMfS, have later suggested that this test might not be appropriate as an off-the-shelf sensitivity test, and this was therefore not pursued further.

The model results presented in both notes above are currently justified through theoretical plausibility rather than empirical evidence (such as the empirical basis of the model formulation, comparison with consensus elasticities, recent trends, or corroborating evidence from other analyses). This underplays the model results and makes it rather hard to reach firm conclusions on the robustness of the findings. It seems therefore helpful to carry out new sensitivity tests as suggested in the next section.

### 3 PHASE 1 AUDIT SUMMARY AND RECOMMENDATIONS

#### 3.1 Summary

Broadly speaking, we consider that the model structure of TELMoS is well designed, with sensible definition and segmentation of land use and economic activities, and linkages between those activities. We consider that the model design and structure are in the main consistent with good practice of land use activity and travel demand modelling.

Our review of the materials supplied during the Phase 1 Audit, nevertheless, has raised a number of real concerns. These concerns are:

- the strength of the empirical underpinnings of the current TELMoS model. These concerns include the use of data sources (or in many cases the lack of them), approach to model calibration and validation, the structure of interface with TMfS, and the maintenance of an audit trail in the use of empirical data.
- the TELMoS-TMfS interface does not appear to be in line with the best practice observed in other models in the UK.

These specific queries would need to be addressed in the next phase of the audit. In summary, there may be an urgent need to i) strengthen the evidence base of TELMoS, and ii) improve the TELMoS-TMfS interface. The potential tasks arising from both aspects can require significant resources in research and model development, and may require much extended overall model run times of the TMfS-TELMoS suite.

Existing presentations of some TELMoS model runs have been reviewed. Whilst they provide useful insights into some aspects of the model operations, they do not appear to address the main queries of the audit. It would be necessary to ascertain responses to the more complex queries through sensitivity tests of the model.

The discussion on TELMoS also has highlighted the need for improvements to data sources, particularly anything that would provide additional information on location choice of households and employment, and on the supply and demand of floorspace. Gaps in the data could undermine the robustness of the model. During the Phase 1 audit there has been scoping for 'preferred Census 2011 tables' as considerations for the longer term data needs.

#### 3.2 Recommendations

Our first recommendation would be **to strengthen the TELMoS Model Description Report**. DSC should be commended for embarking on a documentation task that is multifaceted and very complex. Although the current edition is still uneven and in part incomplete in the treatment of the various modelling issues, it is a good start.

It would be appropriate to revise the Model Description Report in such a way that it would become easier to understand to by interested, non-expert readers (such as the members of the TMfS User Group). This would be useful, in, say, interpreting the model results. In addition to the descriptions of model structure, variable definitions, and model functionality, it should provide a guide to:

- what should/should not be expected from TELMoS
- its bounds of applicability

This should be achievable through strengthening the introductory paragraphs of each technical chapter, and completing key technical data (such as mode choice and distribution model parameters) at the back of each chapter.

Complex technical details (such as those contained in some Project Notes produced for the Phase 1 Audit) should remain in either an indexed and well structured set of Project Notes, or as a series of technical annexes, which are linked back to the main report.

Our other recommendations include:

- a list of technical improvements (they are highlighted in the Findings section above and will not be repeated here)
- a list of desired sensitivity tests
- the roles of Before-and-After studies in strengthening the evidence base for land use modelling
- considerations for future TELMoS model enhancements

### ***Desired sensitivity tests***

This is proposed list of basic sensitivity tests, based on our current review of model documentation. It is intended to be a comprehensive list that can be used to verify the general performance of the model. Two tests that can be done readily have been discussed with DSC; the other tests that could be considered in the short term are listed below and they will need to be scoped by DSC in terms of feasibility in terms of resources available.

For practical reasons, the tests are kept self-contained as far as possible (i.e. running TELMoS only without interface to/from TMfS), because it would be simpler to implement. However, some of the tests are by definition interactive and will have to involve TMfS.

The two tests that could be carried out immediately are:

- a) a re-run of the High Economic Growth Scenario (as documented in DSC Project Note 23 p52), using an alternative assumption of the export profile by industry. This alternative assumption will follow the changing pattern of Scottish exports in the last few years (i.e. declining primary and manufacturing exports, and increasing service exports), and will be different from the assumption adopted in the existing run which followed the pattern in the Input-Output Table of 2002/03. This sensitivity test is expected to show that more growth in employment will occur in the service sectors, rather than in the primary and manufacturing sectors; also the location of employment growth may focus on the central business districts rather than in the rural areas. This test will be helpful to demonstrate the extent that TELMoS can reflect the employment effects of the current trend of industrial restructuring in Scotland.
- b) a test of the changes in passenger-km of commuting travel, comparing a reference case run against a run of say, a global 20% increase in car commuting costs (e.g. the JW run in DSC PN23 p2). This may involve a re-run of the model, or may be do-able by extracting data from an existing run. The test will show the broad level of change in commuting travel demand (measured in person-kms), and hence the implied travel demand elasticity of the TELMoS commuting model. These responses can then be compared with the travel demand elasticities for commuting in TMfS and other operational land use/transport models.

Neither run would require TMfS/TELMoS interaction. Run a) could be run the same way as the High Economic Growth scenario in DSC Project Note 23. Run b) could be undertaken by merely factoring the Transport & Demand Non-Work costs skims and feeding through TELMoS in a similar way to the existing runs - if a model run is required.

The other possible tests that could be considered include:



- c) The demographic transitional model –population growth patterns over time
- d) the development module, especially how to tackle the issue of understating the level of development (which was mainly caused by the input data being insufficient)
- e) car ownership modelling - to verify forecast trends in urban areas and compare with Census trends 1991-2001
- f) commercial and housing rent responses, to ascertain the sensitivity of employment and household location to land development constraints or major new development scheme
- g) changes in the household cost of living and wages, to ascertain that the level of changes in response to different patterns of transport accessibility
- h) freight flow matrices, to ascertain the implied demand responses to changes in freight transport costs
- j) interfacing TMfS and TELMoS with and without interpolating transport cost changes over time

Only Run j) would definitely require the involvement of both TELMoS and TMfS.

Through these tests, we hope DSC would be able to establish appropriate benchmarks that could be used in assessing the reasonableness of future scenario runs. Whilst we understand that there is a resource constraint, it would be beneficial to include as many of the above as possible in the short term programme. The results from these tests may indicate that there is a need for further tests in the medium term.

#### ***The role of before-and-after studies***

In the longer term, well specified before-and-after studies on the land use effects of major transport schemes would help to enhance the evidence base for land use modelling.

These studies will identify the extent of impact of transport schemes on land use, businesses, and households. The data collected for this could be useful for land use model calibration. Furthermore, they could also inform the measurement of the wider economic benefits of the projects, which are often measured through land use/transport modelling.

Currently very little such information exists in Scotland. Existing literature on ex-post studies from outside Scotland should be reviewed. The analysis would benefit from taking a micro-level view on the detailed mechanisms through which firms and households benefit from the transport interventions, and the extent to which the effects would be additional to the cost and time savings already accounted by conventional appraisal.

In order to carry out before-and-after assessments, it would be necessary to collect information prior to the construction of transport schemes. Without proper information on the before-scheme situation, it would be very difficult to identify any effects let alone differentiate the effects. Although by nature such studies are for the longer term, there is a short term task to scope and design appropriate frameworks for data collection and monitoring, such that the evidence is accumulated through time in a consistent manner.

#### ***Future TELMoS model enhancements***

We assume the findings of this report would feed into considerations of future TELMoS model enhancement programme. Many of the findings at this stage are still subject to the proposed sensitivity tests. Also, we recognise that the TELMoS enhancement tasks will need to be coordinated with the work programmes of TMFS:05A, SPTR applications, and TMFS:07, and the associated TMfS auditing tasks.

#### 4 **BIBLIOGRAPHY**

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